DESIGN REPORT

238724

Final Design
Combe Fill South Landfill
Superfund Site
Remedial Construction

Volume 1 of 3

New Jersey Department of
Environmental Protection and Energy

April 1993

O'BRIEN & GERE
ENGINEERS, INC.

FINAL DESIGN REPORT

COMBE FILL SOUTH LANDFILL

SUPERFUND SITE

REMEDIAL CONSTRUCTION

VOLUME 1 OF 3

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

APRIL 1993

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EXECUTIVE SUMMARY

The Record of Decision (ROD) for the Combe Fill South Landfill site identified the following areas to be encompassed within the remedial design:

1. An active collection and treatment system for methane and any other landfill generated gases;
2. Expanded environmental monitoring of water, air, and leachate;
3. A multi-layered cap that covers the landfilled areas and extends under the utility company right-of way;
4. Pumping and on-site treatment of shallow ground water with discharge to Trout Brook;
5. Surface water controls to accommodate runoff from both normal precipitation and severe storms;
6. Security fencing, an access road, and general site preparation.

O'Brien & Gere was retained by the New Jersey Department of Environmental Protection (NJDEP) to develop the Remedial Design of the Combe Fill South Landfill. This report presents the criteria, analyses and resulting design prepared to address the requirements of the ROD.

An analysis of landfill gas generation rates and landfill gas composition was conducted. As a result of this analysis, an active gas collection system consisting of 66 wells connected by piping to exhausters has been designed. Treatment of the extracted gas is accomplished by burning utilizing an enclosed flare.

Expanded environmental monitoring to insure the post construction effectiveness of the shallow ground water pumping and treatment system is presented in this report.

Analyses of the performance of ten multi-layered cap alternatives was conducted. Each cap was evaluated based on its ability to meet performance requirements contained in 40 CFR Part 264 and the New Jersey Administrative Code. The selected cap consists, from the base to the surface, of a two foot thick barrier layer, a one foot thick drainage layer in an envelope of filter fabric, an eighteen inch thick vegetative layer, and a six inch thick layer of vegetated topsoil. In areas of the site having slopes of less than ten percent, a low density polyethylene LDPE liner has been incorporated above the soil barrier layer. In these areas, filter fabric covers only the upper surface of the drainage layer.

Studies of site hydrogeologic conditions resulted in the design of an active shallow ground water collection system consisting of 19 shallow ground water recovery wells installed along the site perimeter. The shallow ground water recovery wells will discharge to an on-site treatment plant. Treatability studies of the shallow ground water were conducted to determine required treatment processes. The characteristics of landfill gas condensate were also considered in the design of the on-site treatment plant. As a result of these studies and considerations, the selected treatment processes include flow equalization, metals removal, biologic treatment, filtration, and carbon adsorption. The treatment plant outfall is to a wetland area forming the headwaters of the east branch of Trout Brook.

Surface water controls consisting of side slope diversion ditches and drainage ditches on the landfill cap, a perimeter drainage ditch, detention basins, and culverts were designed based on an analysis of pre and post construction conditions subjected to appropriate storm events.

A main, paved access road and a gravel perimeter road have been designed to provide access to the site. The remedial design also requires security fencing to be installed around the site following closure.

SECTION 1 - INTRODUCTION

1.01 Background

The Combe Fill South Landfill in Chester and Washington Townships, Morris County, New Jersey, accepted municipal and industrial wastes from the 1940s through 1981. This inactive landfill consists of three separate disposal areas covering about sixty-five acres. Approximately five million cubic yards of waste material are buried within the Combe Fill South Landfill. The majority of the waste includes typical household waste and non-hazardous industrial waste. However, the presence of volatile organic compounds has been identified within both the shallow and deep aquifer, at the site. Additionally, contamination has been detected within nearby potable residential wells.

The Combe Fill South Landfill site was listed on the National Priority Lists in September 1983. Subsequently, a Remedial Investigation/Feasibility Study was conducted from 1984 through 1985 under the lead of the New Jersey Department of Environmental Protection (NJDEP). The Record of Decision (ROD) for this site has identified the following areas to be encompassed within the Remedial Design:

1. An active collection and treatment system for methane and any other landfill generated gases.
2. Expanded environmental monitoring of water, air, soils and leachate.
3. A multi-layered cap that covers the landfilled areas and extends under the utility company right-of-way.
4. Pumping and on-site treatment of shallow ground water with discharge to Trout Brook.

5. Surface water controls to accommodate runoff from both normal precipitation and severe storms.

6. Security fencing, an access road and general site preparation.

O'Brien & Gere was retained by the NJDEP to develop the Remedial Design of the Combe Fill South Landfill.

1.02 Authorization and Scope

In July of 1987, the NJDEP authorized O'Brien & Gere Engineers, Inc. to perform the work necessary to complete the Remedial Design of the Combe Fill South Landfill, as mandated within the ROD. The work is to be conducted in accordance with the Scope of Services outlined within O'Brien & Gere's proposal to the NJDEP dated July 1987.

SECTION 2 - COVER SYSTEM

2.01 General

The Record of Decision for the Combe Fill South Landfill mandated that the remedial design include, among others:

- Capping of the 65-acre landfill in accordance with Resource Conservation and Recovery Act (RCRA) requirements.
- Surface water controls to accommodate seasonal precipitation and storm runoff.
- Security fencing to restrict site access.

This section of the report discusses these components of the remedial design including the fill delineation, cap system, and the grading plan. Surface water controls, site access and site security are also discussed.

2.02 Fill Delineation

The Fill Delineation program was conducted in accordance with the Field Sampling and Testing Plan for the Combe Fill South Landfill. Results of the geophysical survey and aerial photographs were used to select test pit locations to determine the edge of fill.

A total of twenty-nine (29) test pits were excavated during December 1988, located as shown in Appendix 2-1. The test pits were excavated using a rubber tire backhoe using a trenching method. The excavations ranged in size from 45 to 60 feet in length with an average depth of six feet and were backfilled immediately following excavation. Test pit logs and photographs for each excavation are included in Appendix 2-1.

The edge of fill was staked at each test pit location and located using field instrument survey techniques. The location of the edge of fill was developed based on information obtained from the geophysical survey, test pit excavation, aerial photographs, and site topography.

Subsequent to the performance of the fill delineation program and the preparation of the preliminary design, the NJDEP raised concerns that additional areas of fill outside the limits determined by the fill delineation program might be encountered during construction. In order to address these concerns, the design drawings identify areas in which the construction contractor will be required to install test pits prior to refuse regrading. If refuse is encountered in these areas, the refuse will be excavated and placed under the limits of the landfill cover. Methods of test pit excavation are discussed in the technical specifications.

2.03 Cap System

As previously discussed, the ROD requires that the landfill be capped in accordance with RCRA requirements. Federal hazardous waste landfill regulations under RCRA are contained in 40 CFR Part 264. The regulations listed in 40 CFR 264.310 require that a final cover system be designed and constructed to:

- minimize migration of liquids through the closed landfill;
- function with minimum maintenance;
- promote drainage and minimize erosion or abrasion of cover;
- accommodate settling or subsidence so that the integrity of the cover is maintained; and

- have permeability less than or equal to any bottom liner or natural subsoils present, and be repairable to correct settling, subsidence, erosion, etc.

The United States Environmental Protection Agency (USEPA) has developed technical guidelines for the design of final covers for hazardous waste landfills. Recent technical guidance documents state that in order to meet the Federal Regulations, the final cover should consist of as a minimum:

- a 24 inch thick vegetated top layer
- a 12 inch thick drainage layer with a minimum hydraulic conductivity of 1×10^{-2} cm/sec.
- a low permeability layer consisting of a 20 mil. synthetic liner overlying two feet of recompacted soil with a permeability not greater than 1×10^{-7} cm/sec.

Alternate cap designs are permissible, provided that it can be demonstrated that they satisfactorily perform the functions detailed in the regulations. It is noted that previous technical guidance specified that the drainage layer have a minimum hydraulic conductivity of 1×10^{-3} cm/sec.

The New Jersey Administrative Code (NJAC) Subchapter 11-Additional Requirements for Hazardous Waste Facilities Operating Under Existing Facility Status Section 7:26-11.4, require the following at final closure of the landfill.

- Provide long-term minimization of migration of liquids through the closed landfill;
- Function with minimum maintenance;
- Promote drainage and minimize erosion or abrasion of the cover;

- Accommodate settling and subsidence so that the cover's integrity is maintained; and
- Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present.

The preliminary design was developed based on the analyses of performance and cap components of ten (10) proposed cap designs. Foundation and slope stability analyses were performed to evaluate the stability of the landfill when graded to the proposed final elevations. The following sections present the cap performance, cap component, and stability analyses and the analyses of slope and foundation stability. The results of a materials investigation conducted in accordance with the cap system design are also summarized.

2.03.01 Analyses of Cap Performance

The ten alternate cap designs are described below, with cap layers listed from the surface downward. Figures 2-1 through 2-5 illustrate the proposed cap designs.

A.
- 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- 12 inch sand drainage layer
- Geotextile filter

- 30 mil synthetic liner underlying a 6 inch sand bedding layer
- 36 inch soil barrier layer
- Geotextile filter
- 6 inch sand bedding layer

B.
- 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- 12 inch sand drainage layer
- Geotextile filter
- 30 mil synthetic liner underlying a 6 inch sand bedding layer
- 20 mil synthetic liner underlying a 6 inch sand bedding layer
- 6 inch sand bedding layer

C.
- 6 inch topsoil layer
- 18 inch embankment material layer
- Geotextile filter
- 12 inch sand drainage layer
- 30 mil synthetic liner
- 24 inch soil barrier layer
- Geotextile filter
- 12 inch gravel gas venting layer

D. - 6 inch topsoil layer
- 18 inch embankment material layer
- Geotextile filter
- 12 inch sand drainage layer
- Geotextile filter
- 24 inch soil barrier layer
- Geotextile filter
- 12 inch gravel gas venting layer

E. - 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- 12 inch sand drainage layer
- 30 mil synthetic liner
- 24 inch soil barrier layer
- Geotextile filter

F. - 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- 12 inch sand drainage layer
- Geotextile filter
- 24 inch soil barrier layer
- Geotextile filter

G. - 6 inch topsoil layer
- 18 inch vegetative layer

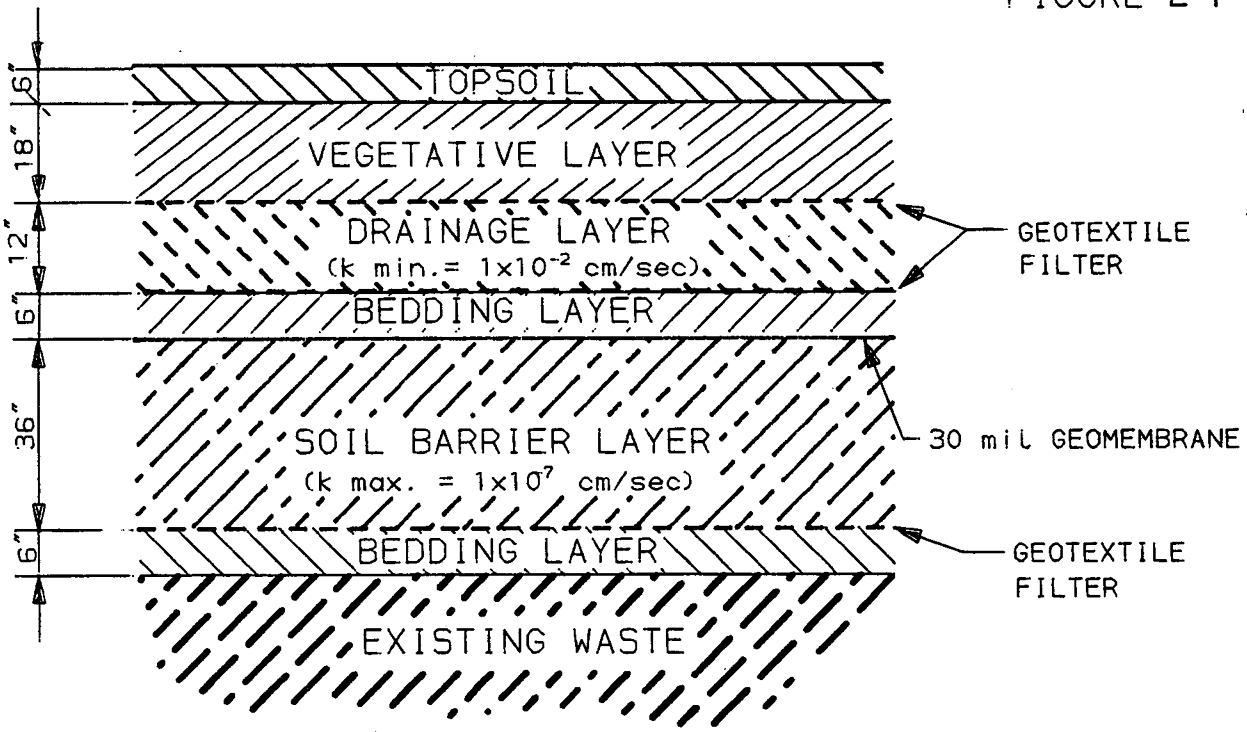
- Geotextile filter
- Synthetic drainage net
- Geotextile filter
- 20 mil synthetic liner
- 24 inch soil barrier layer
- Geotextile filter

H. - 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- Synthetic drainage net
- Geotextile filter
- 24 inch soil barrier layer
- Geotextile filter

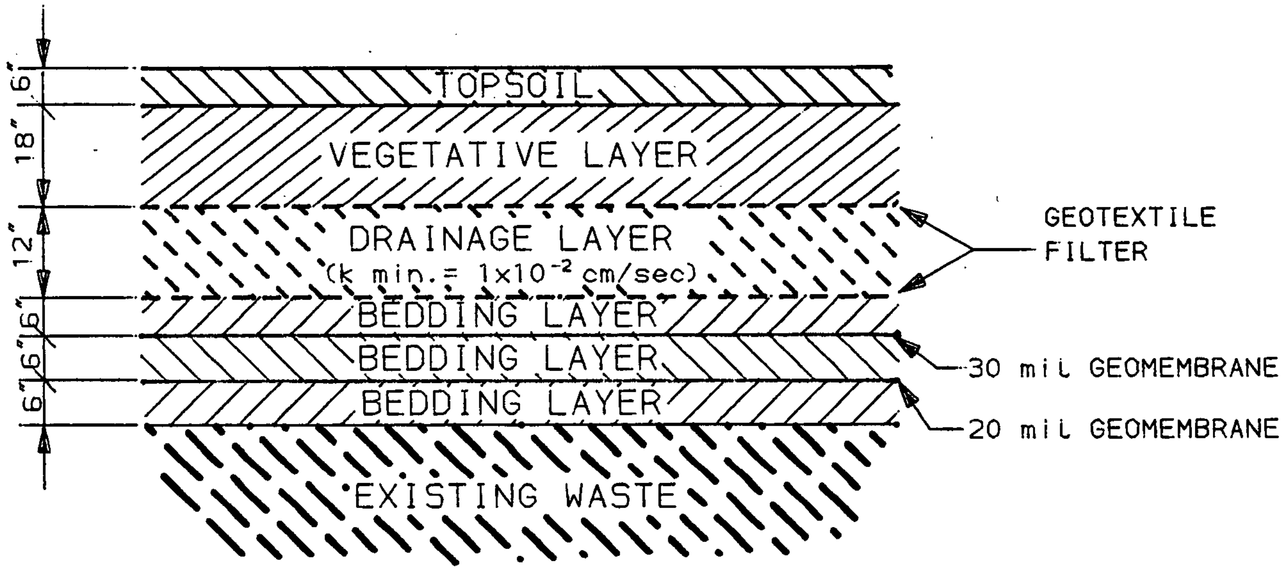
I. - 6 inch topsoil layer
- 18 inch vegetative layer
- Geotextile filter
- 24 inch soil barrier layer
- Geotextile filter

J. - 6 inch topsoil layer
- 18 inch vegetative layer
- 30 mil synthetic liner overlying a 6 inch sand bedding layer

Cap designs A and B meet requirements set forth by Section 7:26-10.8 (h) and (i) of the New Jersey Administrative Code (NJAC). Cap designs C and D represent the cap designs proposed by Lawler, Matusky, and Skelly



PROPOSED CAP DESIGN 'A'



PROPOSED CAP DESIGN 'B'

NOTE: "k" REPRESENTS HYDRAULIC CONDUCTIVITY

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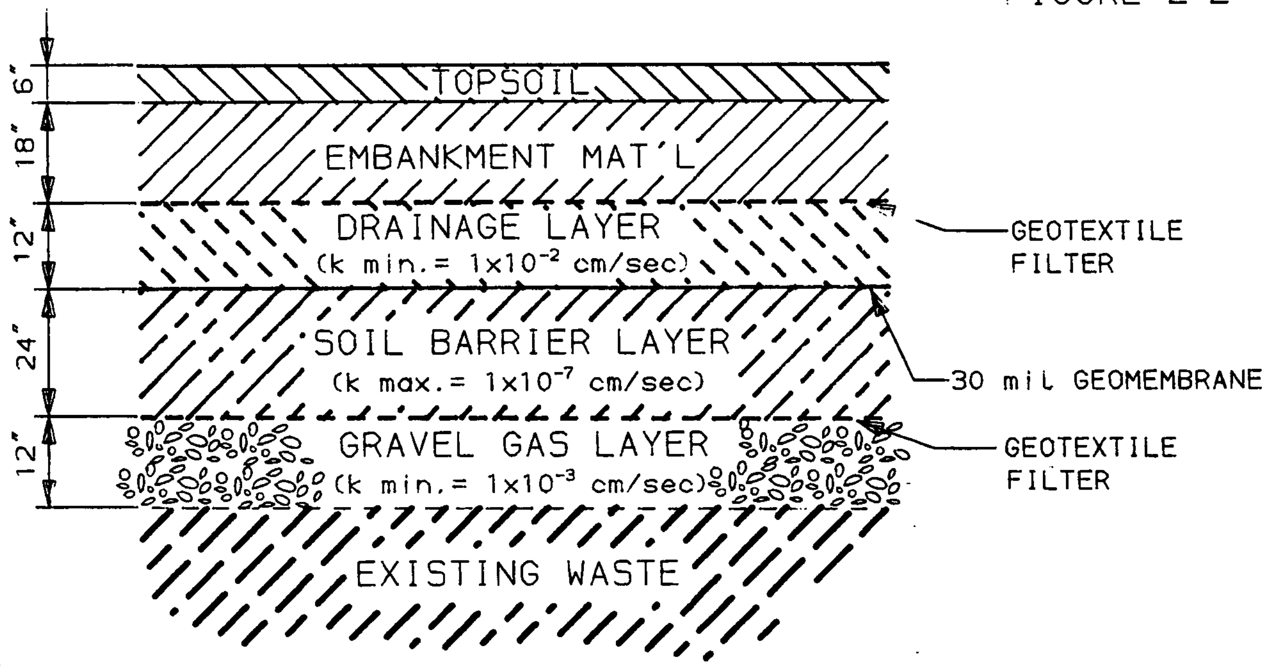
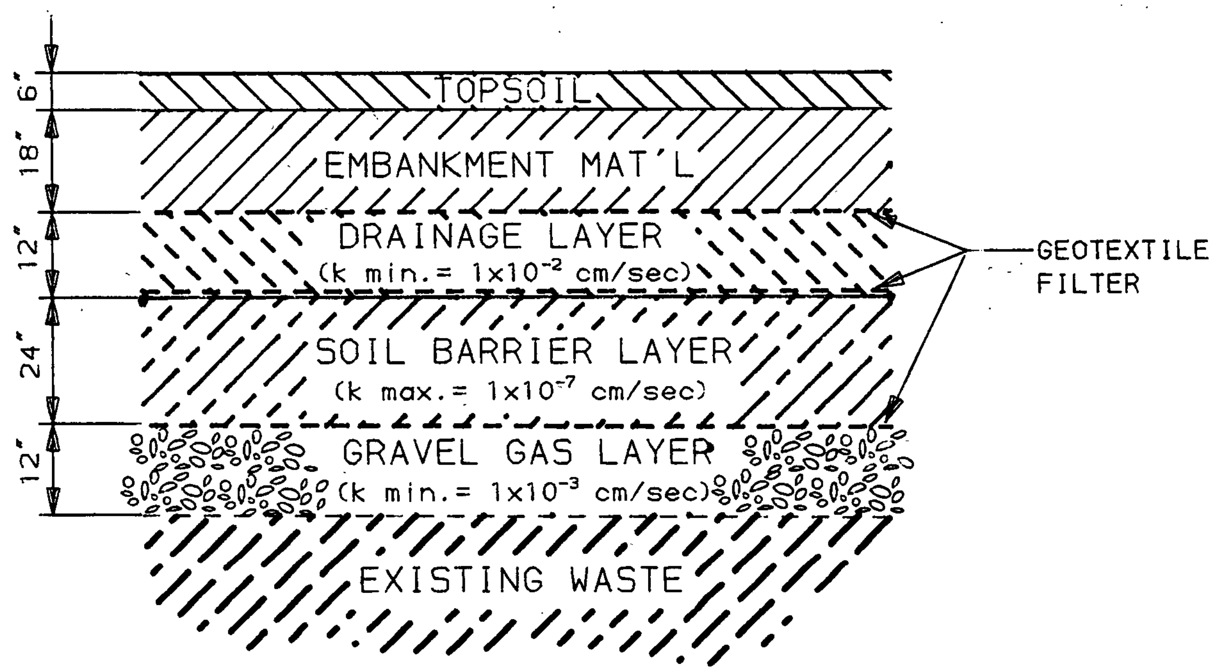
FIGURE 2-2



PROPOSED CAP DESIGN 'C'



PROPOSED CAP DESIGN 'D'

NOTE: "k" REPRESENTS HYDRAULIC CONDUCTIVITY

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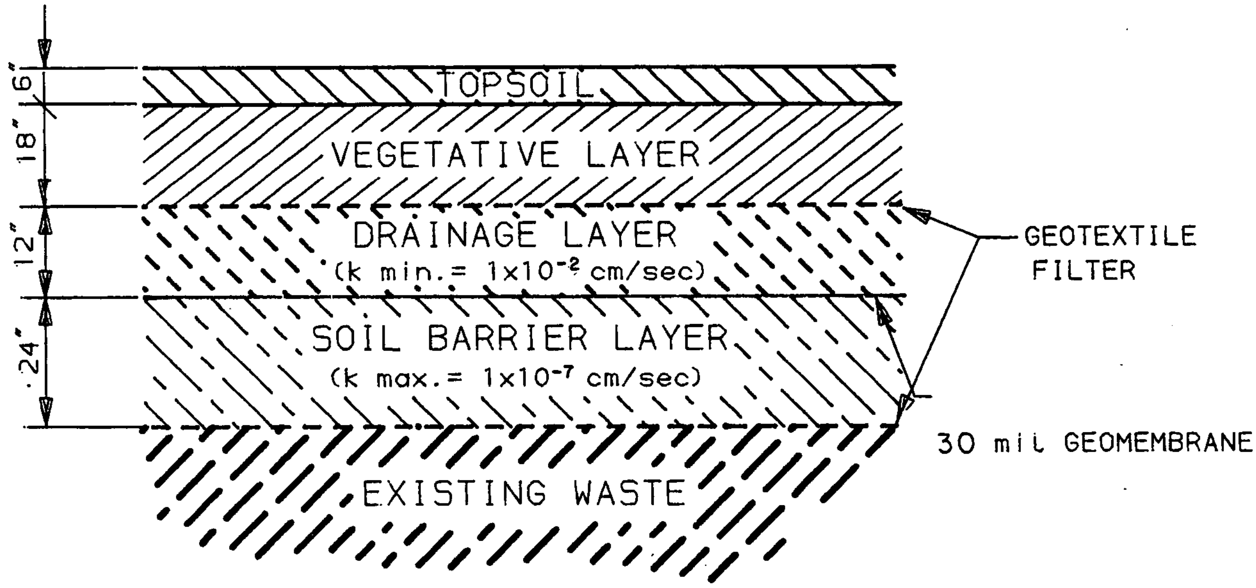
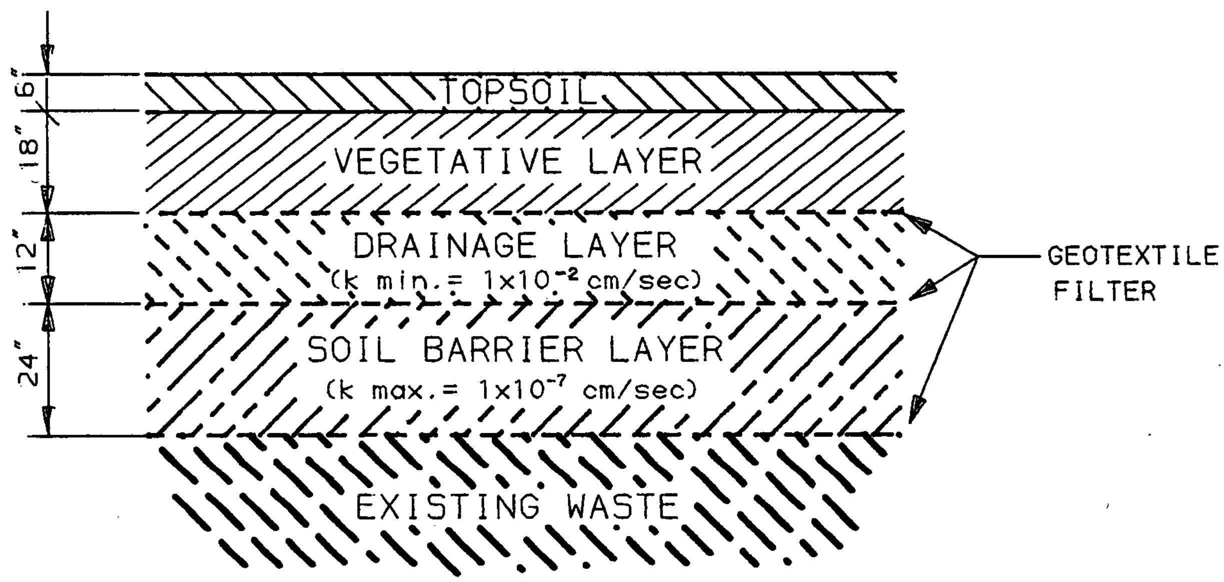
FIGURE 2-3



PROPOSED CAP DESIGN `E'



PROPOSED CAP DESIGN `F'

NOTE: "k" REPRESENTS HYDRAULIC CONDUCTIVITY

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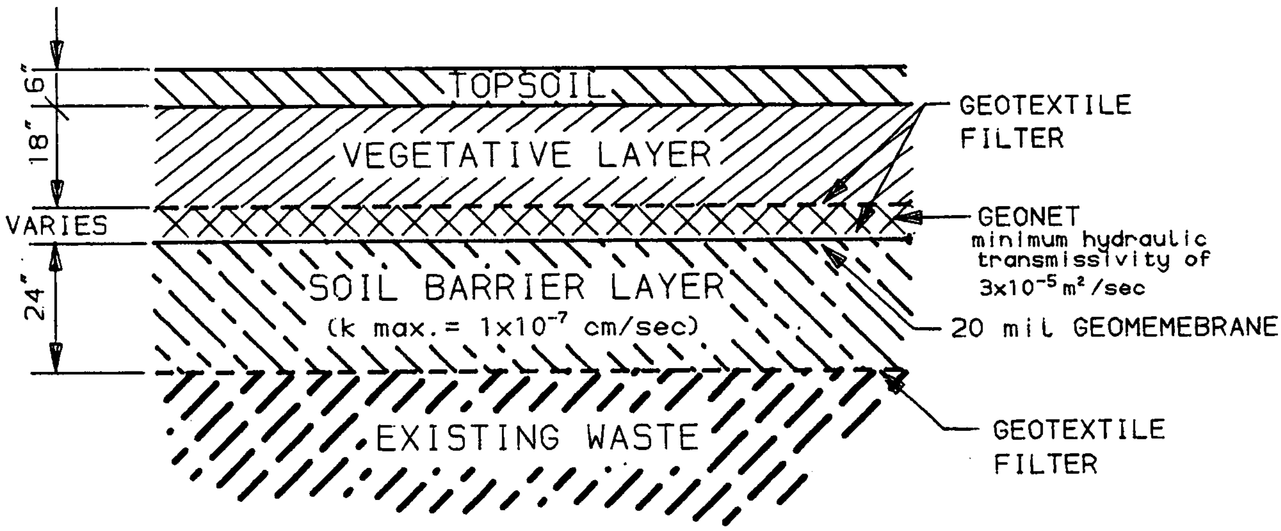
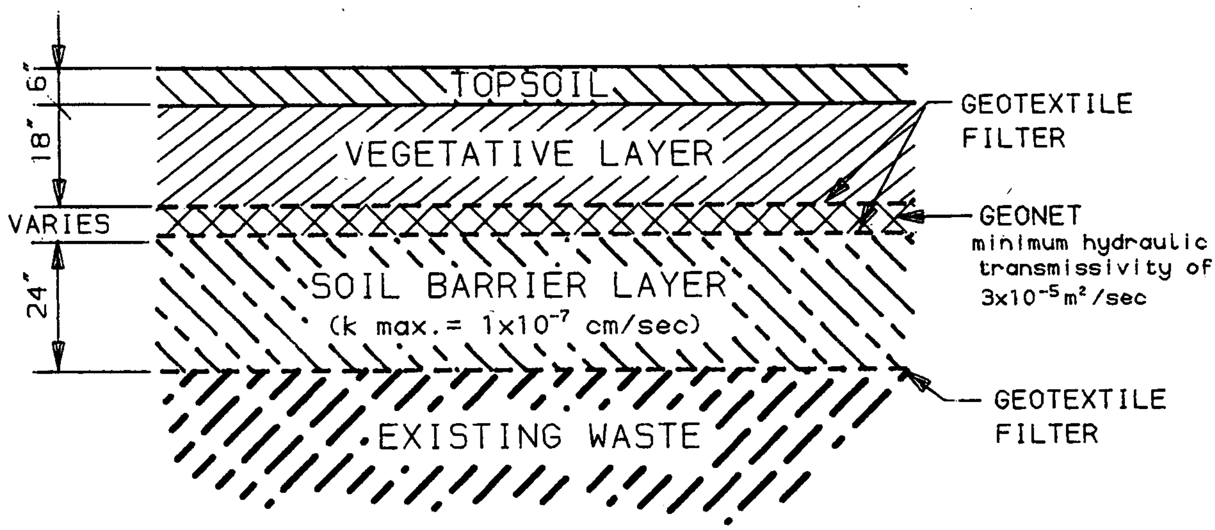
FIGURE 2-4



PROPOSED CAP DESIGN `G'



PROPOSED CAP DESIGN `H'

NOTE: "k" REPRESENTS HYDRAULIC CONDUCTIVITY

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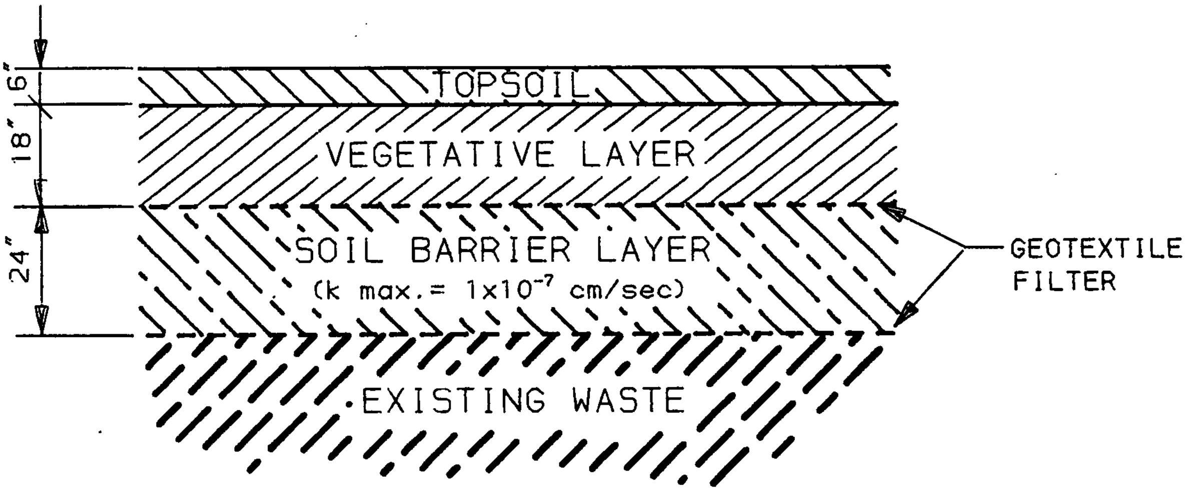
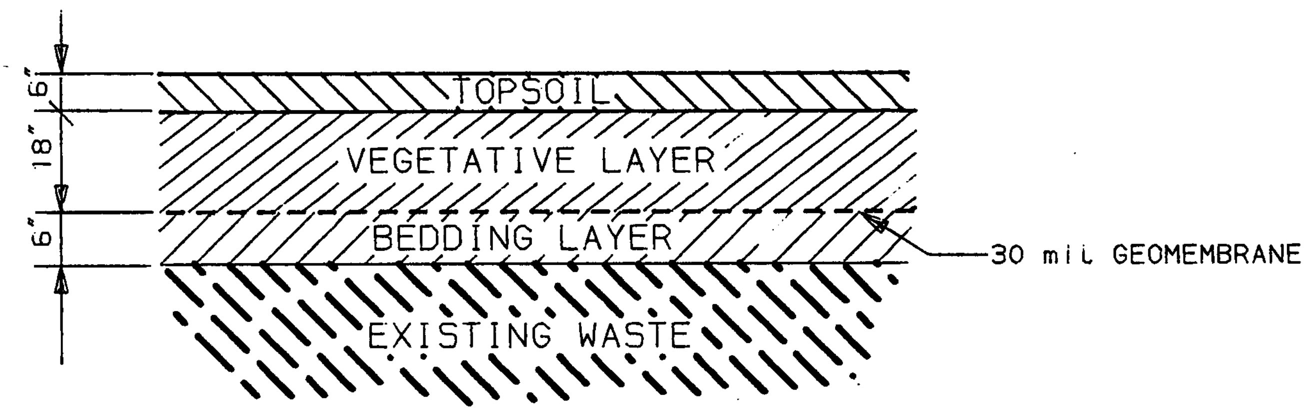
ENGINEERS, INC.

FIGURE 2-5



PROPOSED CAP DESIGN `I'



PROPOSED CAP DESIGN `J'

NOTE: "k" REPRESENTS HYDRAULIC CONDUCTIVITY

COMBE FILL SOUTH LANDFILL
MORRIS CO., NEW JERSEY

O'BRIEN & GERE
ENGINEERS, INC.

Engineers as presented in the Final Conceptual Design Report for the Combe Fill South dated June, 1987. Cap designs E and F meet RCRA guidelines. It is noted that cap designs G and H are similar to designs E and F, respectively, with the exception that a synthetic drainage net is used in lieu of the sand drainage layer. Designs I and J represent alternate designs minimizing the volume of the materials used to construct the cap.

Minimization of Liquid Migration

Integral to the development of a landfill cap design is the development of a water budget. Through utilization of climatologic, soil and other design data, the water balance evaluates the movement of water into, through, across and out of the cap system. The magnitudes of the various components of the water budget for the design alternatives were approximated using the Environmental Protection Agency (EPA) approved Hydrologic Evaluation of Landfill Performance Model (HELP-Version 2). The HELP model was utilized as a screening tool to evaluate the performance of each cap design with respect to minimization of liquid migration. Input parameters for this model are discussed below.

Climatological Input

Rainfall

There are three methods of inputing rainfall data in HELP Version 2 including default, manual, and synthetic methods. The runs of HELP Version 2 used five-year daily default data sets (years 1975-1979) for Edison, New

Jersey. Rainfall data for the Long Valley, New Jersey rain gauging station, the closest station to the site which is located approximately five miles northwest of the landfill, was obtained from the National Climatic Data Center in Ashville, North Carolina. A review of the data indicated that the ranges of precipitation for five- year periods was within the general range of those presented for Edison, New Jersey, and therefore supported use of the Edison defulat data.

Temperature and Solar Radiation

HELP Version 2 utilizes the WGEN model, a synthetic weather generator developed by the Agriculture Research Service, to compute daily values of temperature and solar radiation. The generated daily temperatures and solar radiation values are a function of the rainfall for a given location.

Leaf Area Index (LAI)

HELP Version 2 requires a maximum leaf area index for the site location to compute daily leaf indices by a vegetative growth model. The program prompts for the maximum leaf area index by displaying typical values for different levels of vegetative cover likely to be achieved with the level of management of the landfill. A value of 3.3 corresponding to good grass was input for the maximum leaf area index. The program indicated that a leaf area index of 5 corresponding to excellent grass could not be supported unless irrigated due to low rainfall and short growing season in the area.

Selected Type of Vegetative Cover

The vegetative cover system was modeled as good grass, based on the leaf area index. The vegetative cover stabilizes the cap to promote run-off, minimizes infiltration, and greatly diminishes soil erosion caused by surface run-off. Additionally, the early establishment of a vegetative cover will minimize soil losses through wind erosion and aid in dust control. Several concerns are readily evident in selection of the cover vegetation. The selected species must be adapted to the climate of the region, be relatively quick growing, shallow rooted, able to grow year round, be self propogating, and require a minimum amount of short and long-term maintenance. The vegetation should be hardy enough to withstand severe exposure periods and should be able to withstand attack by indigenous diseases or insects. A seed mixture consisting of Tall Fescue, Spreading Fescue, and Kentucky Bluegrass is recommended as vegetative cover for the cap system. The seed mixture is based on the "Standard for Permanent Vegetative Cover for Soil Stabilization" of the document Standards for Soil Erosion and Sediment Control in New Jersey.

Evaporative Zone Depth

A value of 8 inches was selected as being representative of the evaporative zone depth for the vegetative cover. This root depth corresponds to the evaporative zone depth for bare ground in HELP Version 2 and was selected to represent the minimum amount of precipitation to be removed from the landfill cover by evapotranspiration. As a result, the volume of water which may potentially percolate through the cap cover is maximized and conservatively estimated.

Soil and Design Data Input

Initial Soil Water

The option of allowing the program to calculate the initial soil water contents was used.

Layer Types

HELP Version 2 uses four layer types including vertical percolation layers, lateral drainage layers, barrier soil liners, and barrier soil liners with flexible membrane liners. A vertical percolation layer is a layer of relatively high permeability material without drainage collection systems which allows vertical drainage only. A layer permitting lateral drainage to collection systems or perimeter drains is classified as a lateral drainage layer. Both vertical and lateral drainage are assumed to occur in a lateral drainage layer.

Barrier soil layers restrict vertical flow. The program recognizes two types of barrier layers, those composed of soils alone, and those composed of soil overlain by a geomembrane. When a geomembrane is used, the program requires input of a membrane leakage fraction, which represents the fraction of the area of the soil liner which drains from leaks in the flexible membrane or what fraction of the daily potential percolation through the barrier soil liner is able to occur on a given day. HELP (Version 2) indicates that values of the membrane leakage fraction values may range from 0.01 to 0.00001 depending on liner material, bedding material, construction practice, and Quality Assurance/Quality Control plan. A membrane leakage fraction of 0.00001 was assigned for the initial HELP model analyses based on information presented in the EPA Document "Bottom Liner Performance in Double Lined Landfills and Surface Impoundments". In this document, it is estimated that a flexible membrane liner (FML) installed with good construction quality assurance would be expected to have not more than one to two defects per acre. A standard defect is considered to have an area of 1 cm^2 (0.16 in^2). In an extreme event, up to ten defects may be present per acre. Based on the assumption of ten defects per acre, each with an area of 0.16 in^2, the liner leakage fraction is calculated to be 0.00000026. In order to be conservative, a value of 0.00001 was utilized in the initial HELP model runs.

The topsoil layer was modeled as a 6 inch vertical percolation uncompacted layer utilizing the default soil characteristics corresponding to soil texture 5. Soil texture 5 is classified as a silty sand (SM) according to the Unified Soil Classification System (USCS). Table 2-1 shows the default, unvegetated, and uncompacted soil characteristics for the HELP (Version 2) model. The lower 18 inches of embankment material was modeled as a compacted vertical percolation layer with soil texture 5 default data in the initial HELP model analyses.

In all cases, the drainage layer was modeled as an uncompacted lateral drainage layer. For cases where the drainage layer consisted of soil, the default characteristics corresponding to soil texture 2 were used. Soil texture 2 is classified as a well graded sand (SW) according to the USCS. The

TABLE 2-1

HYDROGEOLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP - VERSION 2)

DEFAULT UNVEGETATED, UNCOMPACTED SOIL CHARACTERISTICS

SOIL TEXTURE HELP	USDA	USCS	POROSITY (VOL/VOL)	FIELD CAPACITY (VOL/VOL)	WILTING POINT (VOL/VOL)	SAT. HYD. CONDUCTIVITY (CM/SEC)
1	CoS	GS	0.417	0.045	0.018	1.0E-02
2	S	SW	0.437	0.062	0.024	5.8E-03
3	FS	SM	0.457	0.083	0.033	3.1E-03
4	LS	SM	0.437	0.105	0.047	1.7E-03
5	LFS	SM	0.457	0.131	0.058	1.0E-03
6	SL	SM	0.453	0.190	0.085	7.2E-04
7	FSL	SM	0.473	0.222	0.104	5.2E-04
8	L	ML	0.463	0.232	0.116	3.7E-04
9	SiL	ML	0.501	0.284	0.135	1.9E-04
10	SCL	SC	0.398	0.244	0.136	1.2E-04
11	CL	CL	0.464	0.310	0.187	6.4E-05
12	SiCL	CL	0.471	0.342	0.210	4.2E-05
13	SC	CH	0.430	0.321	0.221	3.3E-05
14	SiC	CH	0.479	0.371	0.251	2.5E-05
15	C	CH	0.475	0.378	0.265	1.7E-05
16	Liner	Soil	0.430	0.366	0.280	1.0E-07
17	Liner	Soil	0.400	0.356	0.290	1.0E-08
18	Mun.	Waste	0.520	0.294	0.140	2.0E-04
19		USER SPECIFIED SOIL CHARACTERISTICS				
20		USER SPECIFIED SOIL CHARACTERISTICS				

hydraulic conductivity of the material was modified to reflect the minimum required permeability of 1 x 10^{-3} cm/sec for the initial HELP model analyses. This value was later modified to $1x10^{-2}$ cm/sec in accordance with the most recent technical guidelines for the final HELP model analyses. Proposed cap designs G and H utilized a drainage layer consisting of a geotextile filter and a synthetic drainage net. The layer was modeled as a twelve inch thick lateral drainage layer using default soil characteristics for soil texture 1. Soil texture 1 is classified as a sandy gravel (GS) according to USCS. The hydraulic conductivity was changed to 42 cm/sec based on manufacturer's technical data. The changes were introduced to provide better representation of the drainage layer as an artificially porous material rather than as a soil. The geotextile filter was not incorporated in the HELP model analyses.

As previously discussed, the HELP model recognizes two types of barrier layers, those composed of soils alone, and those composed of soil overlain by a geomembrane. In cases where the geomembrane is underlain by a bedding layer, the bedding layer was assigned the default characteristics of soil texture 5. In cases where the geomembrane is underlain by a soil barrier layer, the barrier layer was assigned the default characteristics of soil texture 16. The hydraulic conductivity of the soil is $1x10^{-7}$ cm/sec. As previously noted, a membrane leakage fraction of 0.00001 was utilized for the initial HELP model analyses.

Runoff Curve Number

Default runoff curve numbers were utilized.

Total Area of Cover

A value of 3,310,560 square feet (76 acres) was used to model the area of the cover over the landfill for the initial analyses. This value was based on information available during the initial stages of the preliminary design. In addition, these analyses were performed assuming that the entire area was graded at a three percent slope. This represents a conservative estimate as portions of the landfill cap will be graded at steeper slopes which will likely promote a greater percentage of runoff and drainage from the drainage layer.

2.03.02 Results of Initial Cap Performance Analyses

Detailed copies of the initial runs conducted for the Combe Fill South Landfill are included as Appendix 2-2 of this report. Table 2-2 summarizes the results of the initial analyses. Based on these results, it appears that cap alternatives E, C, and G are most likely to minimize the amount of percolation into the waste layer. Cap Designs A and B allow greater volumes of precipitation to percolate into the waste layer. The greatest volumes of precipitation are estimated to occur with cap designs J, H, I, D, and F. The presence of a gas venting layer underlying the soil barrier layer appears to have a minimal effect on the volume of precipitation entering the waste layer as indicated by the results for cap design C, which incorporates a gas venting layer, and cap design E, which does not include a gas venting layer. Similarly, the difference in the amount of precipitation entering the waste layer for cap designs D and F is minimal.

TABLE 2-2
COMBE FILL SOUTH LANDFILL REMEDIATION PROGRAM
MORRIS COUNTY, NEW JERSEY

INITIAL HELP MODEL (VERSION 2) RESULTS

ALTERNATIVE CAP DESIGN	PERCOLATION INTO WASTE LAYER (gallons/year)
*A	14,300
*B	24,350
*C	25
D	6,034,500
*E	60
F	6,035,450
*G	8
H	876,600
I	4,776,350
*J	57,800

NOTES:
1.) * indicates cap designs where a liner leakage fraction of 0.00001 was assigned.
2.) All analyses were performed for a total landfill cover area of 76 acres graded at 3 per cent slopes. This represents a conservative estimate as portions of the landfill cap will be graded at steeper slopes which will promote a greater percentage of runoff and internal drainage.

2.03.03 Analyses of Cap Components

Cap Component Parameters

In the following sections, the parameters analyzed for each of the cap components are discussed including transmissivity, filtration, sliding stability, and settlement.

The document "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments" by G.N. Richardson and R.M. Koerner, prepared for the United States Environmental Protection Agency (USEPA), was used as a guide for the analyses. Koerner's book Designing with Geosynthetics (1986) was also used as a reference.

Transmissivity

This section applies to cap designs where a geosynthetic material is utilized in lieu of granular material as part of the Surface Water Collection/Removal (SWCR) system. A geosynthetic system used to replace the granular bedding layer on top of the Flexible Membrane Cover (FMC) must provide sufficient planar flow capacity to prevent surface water from accumulating and standing on the FMC. Recent Minimum Technology guidance for covers indicates that geosynthetic materials utilized for the drainage layer must exhibit performance equivalent to soil with a minimum hydraulic transmissivity of 3×10^{-5} m^2/sec. Richardson and Koerner recommend a DR (ratio of geosynthetic transmissivity to required transmissivity) of 10. The transmissivity of a geosynthetic is influenced by the flow gradient, the normal load on the system, and the long-term creep compressibility characteristics of the geosynthetic. For long-term transmissivity, Richardson and Koerner recommend a DR of 5. It is noted that analysis of this parameter is not required for cap designs where the SWCR system consists of a soil drainage layer.

SWCR Filtration

The SWCR system must incorporate a properly designed filter fabric into that surface that is adjacent to the cover soil. This fabric must be selected to allow the flow of water, yet prevent the movement of soil fines into the core of the SWCR. Filter criteria are based on empirical grain size relationships.

The analyses were performed assuming cover soil gradations as recommended by Richardson and Koerner. Soil gradations corresponding to the results of laboratory analyses performed on materials likely to be used for the vegetative layer were compared to the recommended cover soil gradations when they became available. The soils generally had grain size characteristics within the ranges of those recommended by Richardson and Koerner. Typical properties of geotextiles were used in the analyses.

Analyses were performed to determine the soil retention properties of the filter fabric and the permittivity (cross-plane flow). For the soil gradations used, it appears that there are several geotextiles available with properties which would sufficiently retain fine soil particles. Analyses for permittivity were performed with the peak daily flow rate through the drainage layer, which exceeded the daily flow rate based on average yearly flow. In addition, analyses were performed using an assumed head of 12 inches and the maximum head of 38 inches calculated in the corresponding HELP model runs. As stated by Richardson and Koerner (pg. V-5), "Unlike the LCR (Leachate Collection/Removal) systems, no maximum head is currently specified by statute or MTG (Minimum Technology Guidance) criteria. In that the FMC must have a permeability equal to or less than the thickest Flexible Membrane Liner (FML), it would seem reasonable to design the FMC for a maximum tolerable surface water head of one foot. The design amount of water entering the system would therefore roughly equal the amount of leachate passing through the liner system". It is noted that the HELP model runs indicate that a head of water greater than one foot may be imposed on the FMC. It is likely that this head represents a maximum and may decrease in areas of the cap where steeper slopes promote drainage. Based on the results of the analyses, it appears that there are several geotextile materials with properties which would meet the requirements for permittivity.

Geotextiles used as filters in landfill and hazardous waste applications are generally heavier fabrics, with material weights ranging from 8 oz/yd^2 to 16 oz/yd^2. The purpose of using a heavier fabric is to provide a material with properties sufficient to withstand construction conditions. The geotextile is generally subjected to the greatest stresses during installation.

SWCR Sliding

The SWCR system must be analyzed to evaluate the likelihood of shear failures occurring at the surface or interior boundaries of the cap system. The Design Ratio (DR) against soils sliding on components of the cap is the ratio of the tangent of the friction angle of the SWCR/soil interface and the tangent of the slope angle. The minimum DR recommended by Richardson and Koerner against soils sliding on components of the cap is 2.

The minimum friction angle for the component of the SWCR portion of the cap was taken to be that of the geotextile against the vegetative layer for the majority of the cap designs. The friction angle for this interface was assumed to be 25 degrees based on information presented in Koerner (1986). For cap designs G and H, where a geosynthetic was proposed for use as the SWCR, the minimum friction angle was taken to be that of the geotextile against the geosynthetic drainage material. Lundell and Menoff indicate that when geonets and geotextiles are placed adjacent to geomembranes, the interfaces tend to have the lowest laboratory measured friction angles. Minimum friction angles of 15 to 17 degrees have been reported for geonet/geomembrane inter faces. Minimum friction angles on the order of 6 degrees have been reported for geotextile/geomembrane interfaces. Lundell and Menoff concluded that friction angles closer to those of geotextile/geomembrane interfaces can be measured in the laboratory for geonet/geomembrane interfaces. The friction angle was assumed to be nine degrees based on information presented by Gundle Lining Systems, Inc. It is not intended to specify Gundle materials in particular. However, literature from Gundle in addition to information presented by Koerner (1986) provided information on friction angles developed at various soil/geosynthetic and geosynthetic/geosynthetic interfaces.

FMC Sliding

As with the SWCR system, the flexible membrane cover (FMC) must be analyzed to evaluate the likelihood of shear failures occurring at the interior boundaries of the cap system. The friction angle utilized for the analyses was taken to be the minimum friction angle developed at the interface above or below the FMC. As previously discussed, values for the friction angles developed at these interfaces were based on information presented by Gundle and in Koerner (1986). It is noted that this information corresponds to a series of experiments performed with various soil/geosynthetic and geosynthetic/geosynthetic interfaces and represent general values. Behavior of the materials in the field may vary due to differences in soil type and installation of the geosynthetic materials.

Four types of materials proposed for use as flexible membrane covers (FMC) were evaluated including high density polyethylene (HDPE), low density polyethylene (LDPE), polyvinyl chloride (PVC), and chlorosulfonated polyethylene (CSPE). Based on available literature, it appears that the angle of internal friction developed at the PVC, CSPE, and LDPE and geotextile or sandy soil interfaces are generally greater than those developed at smooth HDPE and geotextile or sandy soil interfaces. Koerner (1986) indicates that the angle of internal friction developed at smooth PVC and sandy soil interfaces ranges from 21 to 25 degrees. Minimum friction angles measured at PVC/clay interfaces are in the range of 16 to 17 degrees. The angle of friction developed for smooth HDPE and sandy soil interfaces ranges from 17 to 18 degrees. Similarly, the minimum friction angles measured at HDPE/-clay interfaces are in the range of 15 to 17 degrees. Manufacturer's literature from Poly-America indicate that the angle of internal friction developed at LDPE and sandy soil interfaces range from 17 to 21 degrees. It is noted that a friction angle of 17 degrees corresponds to a test condition of LDPE and saturated Ottawa sand. This is not intended to specify Poly-America products and is used only as a reference for typical friction angles. Data corresponding to LDPE/clay interfaces does not appear to be readily available. CSPE and sandy soil interfaces have friction angles ranging from 21 to 25 degrees. The information referenced corresponds to a series of experiments performed with various soil/geosynthetic and geosynthetic/ geosynthetic interfaces and represent general values. Behavior of the materials in the field may vary due to differences in soil type and installation of the geosynthetic materials.

Based on available literature, it appears that PVC and LDPE materials have higher elongations at yield than HDPE and CSPE materials. Therefore, PVC and LDPE materials have significantly larger factors of safety with respect to strains at rupture to avoid FMC failure due to settlement.

It is noted that geosynthetic material used as Flexible Membrane Covers (FMCs) are generally exposed to surface water infiltration only. As a result, chemical compatibility is generally not a concern. However, HDPE materials are generally more chemically resistant to a wider range of parameters than PVC and LDPE materials. In summary, PVC or LDPE materials appear to be more advantageous in cases where the FMC is likely to be subjected to significant settlements because of their more favorable stress-strain characteristics. In cases where chemical compatibility is of a concern, the use of HDPE materials may be more favorable because of their resistance to a wider range of chemicals. Recognizing that a two foot thick soil barrier layer will likely separate the waste layer from the FMC in the selected cap design and in order to accommodate settlement of the cap system, a FMC manufactured of PVC or LDPE appears to be most appropriate.

LDPE materials exhibit higher tensile strength and more favorable stess-strain behavior than PVC. In addition, manufacturer's literature indicates that LDPE materials typically have low temperature brittleness values ranging from -94 to -112 degrees Farenheit while PVC typically has low temperature brittleness factors on the order of -45° Farenheit. Therefore, LDPE materials are recommended as part of the cap system due to its more favorable stress-strain characteristics and low temperature brittleness values. In the following analyses, minimum values of friction angles developed at LDPE/Sandy Soil or PVC/clay or geosynthetic interfaces were used. Friction angle values for PVC/clay or geosynthetic interfaces were used as a reference due to the apparent absence of LDPE/clay interface friction angle data.

A textured HDPE liner has been developed by Gundle Lining Systems, Inc. which is manufactured with a specially treated surface which increases the angle of friction. The angles of internal friction developed at the interface of the textured material and adjacent soil or geosynthetic materials appear to be equal to or greater than those developed at the rough PVC, CSPE, and LDPE interfaces. It is not meant to specify products manufactured by Gundle Lining Systems in particular. It is noted that the use of the textured HDPE material may be dismissed based on additional cost and apparent difficulties in seaming due to the textured surface increased thickness. However, analyses were performed utilizing the properties of textured HDPE to illustrate its influence on the maximum allowable slopes.

Settlement

Stresses introduced to the geotextile and geomembrane during their service life are caused by differential settlements of the waste below the cap. It is important that the strain at rupture for geotextile and FMC be known and specified to avoid failure due to settlement. However, it is difficult, to estimate landfill settlement. It is impossible to predict random settlement events such as the collapse of drums or the occurrence of stumps and demolition debris which inhibit settlement.

A settlement analysis was performed to estimate settlement of the waste layer caused by construction of the cap system. The analysis was performed based on information presented in "Settlement of Waste Disposal Fills" by George F. Sowers included in the Proceedings of the 8th International Conference on Soil Mechanics and Foundation Engineering in Moscow, 1973. It appears that several mechanisms are responsible for settlement, including mechanical, ravelling of fines, physico-chemical decay, and interaction. Of these mechanisms, only the first is load related and can be analyzed in terms of the stresses involved. The other mechanisms are related to the environment due to air, moisture, and temperature conditions and cause settlements similar to secondary settlement in soils. The mechanical or primary settlement occurs rapidly with little or no pore pressure build-up and is usually completed in less than one month following application of load. The magnitude of settlement is dependent on the initial void ratio of the waste layer, compression index, and applied surcharge. Based on information presented in the paper, typical void ratios for waste vary between 2 for well-compacted and 15 for uncompacted conditions, respectively. Analyses performed for estimating the magnitude of primary settlement were based on the following assumptions:

- initial void ratio = 10;
- compression index = 3.5;
- maximum height of waste layer = 80 feet;
- unit weight of waste material = 90 pcf;
- waste material is normally consolidated;
- surcharge due to 5 foot thick cap system = 600 psf.

The analyses indicated that approximately 2.7 feet of settlement may occur for the conditions modeled. Analyses for primary settlement are presented in Appendix 2-3. It is noted that this estimate corresponds to areas where the thickness of the waste layer is approximately 80 feet and that less settlement is anticipated in areas where the thickness of the waste layer is less than 80 feet. Differential settlement may occur in areas where the cap system is constructed due to variations in waste composition and density, changes in the manner in which waste was placed, or potentially unstable areas within the landfill.

Additional analyses were performed to estimate the magnitude of secondary settlement in the waste layer. As previously discussed, the amount of secondary settlement is related to mechanical secondary compression, physico-chemical action, and bio-chemical decay. Analyses performed estimating the magnitude of secondary settlement were based on the following assumptions:

- filling at site commenced in 1940;
- initial void ratio = 10;
- secondary compression factor = 0.45;
- maximum height of waste layer;
- cap-installed in 1990;
- assumed design life of 30 years (to year 2020).

It should be noted that since the cover will be installed subsequent to 1990, actual settlements may be slightly less than actually predicted.

The analyses indicated that approximately 0.6 feet of secondary settlement may occur for the conditions modeled. Detailed analyses for secondary settlement are also presented in Appendix 2-3. As previously discussed, this estimate corresponds to areas where the thickness of the waste layer is approximately 80 feet and that less settlement is anticipated in areas where the thickness of the waste layer is less than 80 feet. Therefore, the total estimated settlement is estimated to be approximately 3.3 feet for the conditions modeled.

Based on analyses presented in "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments" by Richardson and Koerner, an estimated total settlement of 3.3 feet corresponds to a settlement ratio of 0.04. Information presented by Knipshield in "Material Selection and Dimensioning of Geomembranes for Goundwater Protection" in Waste and Refuse indicates that a settlement ratio of 0.04 corresponds to a uniform strain of approximately one (1) percent. Richardson and Koerner recommend a minimum DR, ratio of the strain at rupture for the geomembrane to the estimated uniform strain due to settlement, of 5.

2.03.04 Results of Cap Component Analyses

Individual analyses of the cap components for the cap designs are as follows:

CAP DESIGN A

A.I. Transmissivity

This section applies to cases where a geosynthetic system is utilized in lieu of granular material as part of the Surface Water Collection/Removal (SWCR) system. Cap A utilizes a granular material for the drainage layer overlying the Flexible Membrane Cover (FMC) and underlying soil barrier layer. Therefore, analysis of the transmissivity of the SWCR was not required for Cap A.

A.II. SWCR Filtration

As discussed in section describing SWCR filtration, it appears that there are several geotextile filters available with properties which would meet requirements for permittivity.

A.III. SWCR Sliding

The friction angle for the vegetative layer/geotextile interface was assumed to be 25 degrees based on information presented in Koerner (1986). The maximum slope for a DR of 2 is 1 vertical on 4.3 horizontal (23 percent).

A. IV. FMC Sliding

For cap A, the minimum friction angle for the component of the FMC portion of the cap was taken to be that of the geomembrane adjacent to the soil barrier layer based on test results supplied by Gundle Lining Systems, Inc., Koerner (1986), and Poly-America, Inc. It is not intended, however, to specify Gundle or Poly-America products. It is noted that the angle of internal friction between geosynthetic materials and soil is most accurately determined with laboratory testing utilizing the materials to be used in construction. The friction angle for the FMC/soil barrier layer interface was assumed to be 17 degrees based on information for LDPE materials. The maximum slope for a DR of 2 and an angle of friction of 17 degrees is 1 vertical on 6.5 horizontal (15 percent).

Textured Gundline HDPE material is manufactured with a specially treated surface which increases the angle of friction. It is noted that textured Gundline HDPE is manufactured in thicknesses of 40 mils and greater only.

The friction angle for the FMC/sand bedding layer interface was assumed to be 38 degrees based on information for the textured Gundline material. The maximum slope for a DR of 2 and an angle of friction of 38 degrees is 1 vertical on 2.6 horizontal (38 percent).

Based on results of analyses evaluating sliding of the SWCR and the FMC, it appears that the maximum slope for a DR of 2 is 1 vertical on 6.5 horizontal (15 percent) when LDPE is used. In this case the maximum allowable slope is governed by the friction angle at the geomembrane/soil barrier layer interface. The maximum slope for a DR of 2 when textured HDPE is used is 1 vertical on 4.3 horizontal (23 percent). In this case, the maximum allowable slope is governed by the friction angle at the vegetative layer/geotextile interface.

A.V. Settlement

Analyses performed for LDPE materials show that these materials will have sufficient strains at rupture to avoid FMC failure due to settlement for the conditions modeled. Analyses performed for the geotextile filter showed that the material would likely have sufficient strength to avoid failure due to settlement for the conditions modeled.

CAP DESIGN B

B.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

B.II. SWCR Filtration

Identical to results for Cap Design A. (See section A.II)

B.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.III)

B.IV. FMC Sliding

Identical to results for Cap Design A. (See Section A.IV)

B.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN C

C.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

C.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.II)

C.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.III)

C.IV. FMC Sliding

For cap C, the minimum friction angle for the component of the FMC portion of the cap was taken to be that of the geomembrane adjacent to the soil barrier layer based on test results supplied by Gundle Lining Systems, Koerner (1986), and Poly-America as previously discussed. The friction angle for the LDPE/soil barrier interface was assumed to be 17 degrees. The maximum slope for a DR of 2 and an angle of friction of 17 degrees is 1 vertical on 6.5 horizontal (15 percent)

The friction angle for the FMC/soil barrier layer interface was assumed to be 25 degrees based on information for the textured Gundline material. The maximum slope for a DR of 2 and an angle of friction of 25 degrees is 1 vertical on 4.3 horizontal (23 percent).

Based on results of analyses evaluating sliding of the SWCR and the FMC, it appears that the maximum slope for a DR of 2 is 1 vertical on 6.5 horizontal (15 percent) when LDPE is used. In this case the maximum allowable slope is governed by the friction angle at the FMC/soil barrier layer interface. The maximum slope for a DR of 2 when textured HDPE is used is 1 vertical on 4.3 horizontal (23 percent). In this case, the maximum allowable slope is governed by the friction angle at the vegetative layer/geotextile interface.

C.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN D

D.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

D.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.II)

D.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.III)

D.IV. FMC Sliding

This analysis was not required as Cap Design D did not utilize a FMC.

D.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN E

E.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

E.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.II)

E.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.III)

E.IV. FMC Sliding

Identical to results for Cap Design C. (See Section C.IV)

E.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN F

F.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

F.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.II)

F.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.III)

F.IV. FMC Sliding

This analysis was not required as Cap Design F did not utilize a FMC.

F.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN G

G.I. Transmissivity

Two types of geosynthetic materials were evaluated for use as the SWCR. These materials include geonet material manufactured of HDPE and a geocomposite material manufactured from HDPE with geotextile materials heat sealed over both sides of the geonet. The properties of Gundnet XL-4 were used to evaluate the geonet. Properties corresponding to Tenax TNT were used to evaluate the geocomposite material. As previously discussed, this is not meant to specify these materials in particular. The properties were used as a basis for determining the general material properties of such materials. Based on analyses performed and available information, it appears that Gundnet XL-4 would provide sufficient transmissivity for the conditions analyzed. It appears that the geocomposite material does not provide sufficient transmissivity for the conditions analyzed.

It is noted that these analyses are conservative as the peak daily flow were used as the design flows. The peak daily flows exceeded the average daily flows based on the average yearly flows.

G.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.II)

G.III. SWCR Sliding

For cap G, the minimum friction angle for the component of the SWCR portion of the cap was taken to be that of the geotextile against the geosynthetic drainage layer. The friction angle for this interface was assumed to be nine degrees based on information presented in the test results from

Gundle previously discussed. The maximum slope for a DR of 2 is 1 vertical on 12.6 horizontal (18 percent).

As discussed by Richardson and Koerner, the shear stresses transferred into the SWCR by the cover soil must not exceed the shear strength of the SWCR itself. It is likely that tensile forces may develop in the geosynthetic drainage layer due to an imbalance in the shear stresses acting on the upper and lower interfaces of the layer. It is important to note that the tensile strength of many geosynthetic drainage materials have not been formalized to date. Information was requested from Gundle regarding tensile strength for Gundnet XL-4. However, this information is not readily available.

G.IV. FMC Sliding

For cap G, the minimum friction angle for the component of the FMC portion of the cap was taken to be that of the geomembrane adjacent to the geosynthetic drainage layer based on test results supplied by Gundle Lining Systems, Inc. The friction angle for the geotextile/geomembrane interface was assumed to be nine degrees based on information for the untextured Gundline material. The maximum slope for a DR of 2 and an angle of friction of nine degrees is 1 vertical on 12.6 horizontal (8 percent).

The friction angle for the FMC/sand interface was assumed to be 32 degrees based on information for the textured Gundline material. However, sliding of the FMC and SWCR system is governed by the friction angle of nine degrees between the geotextile and geosynthetic drainage layer.

G.V. Settlement

See Section A.V for Cap Design A. Analyses to determine if the geosynthetic materials proposed for used in the SWCR require information regarding the tensile strengths of the materials. It is important to note that the tensile strength of many geosynthetic drainage materials have not been formalized to date.

CAP DESIGN H

H.I. Transmissivity

Identical to results for Cap Design G. (See Section G.I)

H.II. SWCR Filtration

Identical to results for Cap Design G. (See Section G.II)

H.III. SWCR Sliding

Identical to results for Cap Design G. (See Section G.III)

H.IV. FMC Sliding

This analysis was not required as Cap Design H did not utilize a FMC.

H.V. Settlement

Identical to results for Cap Design G. (See Section G.V)

CAP DESIGN I

I.I. Transmissivity

This analysis was not required as Cap Design I did not utilize a SWCR.

I.II. SWCR Filtration

Identical to results for Cap Design A. (See Section A.I)

I.III. SWCR Sliding

Identical to results for Cap Design A. (See Section A.II)

I.IV. FMC Sliding

This analysis was not required as Cap Design I did not utilize a FMC.

I.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

CAP DESIGN J

J.I. Transmissivity

Identical to results for Cap Design A. (See Section A.I)

J.II. SWCR Filtration

This analyses was not required as Cap Design J did not utilize a geotextile filter.

J.III. SWCR Sliding

This analysis was not required as Cap Design J did not utilize a SWCR.

J.IV. FMC Sliding

For cap J, the minimum friction angle for the component of the FMC portion of the cap was taken to be that of the geomembrane adjacent to the vegetative layer. The friction angle for the FMC/soil barrier interface was assumed to be 17 degrees based on information presented by Gundle, Koerner (1986), and Poly-America. The maximum slope for a DR of 2 and an angle of friction of 17 degrees is 1 vertical on 6.5 horizontal (15 percent).

The friction angle for the FMC/vegetative layer interface was assumed to be 25 degrees based on information for the textured Gundline material. The maximum slope for a DR of 2 and an angle of friction of 25 degrees is 1 vertical on 4.3 horizontal (23 percent).

Based on results of analyses evaluating sliding of the SWCR and the FMC, the maximum slope for a DR of 2 is 1 vertical on 6.5 horizontal (15 percent) when LDPE is used. In this case the maximum allowable slope is governed by the friction angle at the FMC/soil barrier layer interface. The maximum slope for a DR of 2 when textured HDPE is used is 1 vertical on 4.3 horizontal (23 percent). In this case, the maximum allowable slope is governed by the friction angle at the vegetative layer/geotextile interface.

J.V. Settlement

Identical to results for Cap Design A. (See Section A.V)

Results of the analyses performed are summarized in Table 2-3. It is noted that the maximum slopes listed in this table correspond to analysis of the cap components. The maximum slopes required for a factor of safety of two against sliding for the SWCR layer and the FMC layer of each cap design are listed. The controlling maximum slope is also listed for each proposed cap design. The maximum allowable slope for cap designs A, B, C, D, E, and J for a factor of safety of two is 1 vertical on 4.3 horizontal (23 percent) if textured HDPE material is used. For cases where LDPE material is used, the maximum allowable slope is 1 vertical on 6.5 horizontal (15 percent) for cap

TABLE 2-3
COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY
INITIAL RESULTS OF CAP COMPONENTS ANALYSES

ALTERNATE CAP DESIGN	SWCR TRANSMISSIVITY	GEOTEXTILE FILTER FABRIC (soil retention/ permittivity)	SWCR SLIDING	FMC SLIDING	MAXIMUM SLOPE	SETTLEMENT
A	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	FSmin=2 with 1:3.5 slopes if **textured HDPE is used FSmin=2 with 1:6.5 slopes if LPDE is used	1:4.3 textured HDPE 1:6.5 LDPE	acceptable for geomembrane geotextile
B	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	FSmin=2 with 1:3.5 slopes if **textured HDPE is used FSmin=2 with 1:6.5 slopes if LPDE is used	1:4.3 textured HDPE 1:6.5 LDPE	acceptable for geomembrane geotextile
C	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	FSmin=2 with 1:4.3 slopes if **textured HDPE is used FSmin=2 with 1:6.5 slopes if LPDE is used	1:4.3 textured HDPE 1:6.5 LDPE	acceptable for geomembrane geotextile
D	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	N/A	1:4.3	acceptable for geotextile
E	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	FSmin=2 with 1:4.3 slopes if **textured HDPE is used FSmin=2 with 1:6.5 slopes if LPDE is used	1:4.3 textured HDPE 1:6.5 LDPE	acceptable for geomembrane geotextile
F	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	N/A	1:4.3	acceptable for geotextile
G	GUNDNET XL-4 or equal	Several geotextiles capable of meeting criteria	****FSmin=2 with 1:12.6 slopes if GUNDNET XL-4 or equal is used	****FSmin=2 with 1:10.2 slopes if **textured HDPE is used	1:12.6	acceptable for geomembrane geotextile *geonet
H	GUNDNET XL-4 or equal	Several geotextiles capable of meeting criteria	****FSmin=2 with 1:12.6 slopes if GUNDNET XL-4 or equal is used	N/A	1:12.6	acceptable for geotextile *geonet
I	soil layer as specified	Several geotextiles capable of meeting criteria	***FSmin=2 with 1:4.3 slopes	N/A	1:4.3	acceptable for geotextile
J	soil layer as specified	N/A	N/A	FSmin=2 with 1:4.3 slopes if **textured HDPE is used FSmin=2 with 1:6.2 slopes if LPDE is used	1:4.3 textured HDPE 1:6.5 LDPE	acceptable for geomembrane

NOTES:
1.) SWCR represents Surface Water Collection and Recovery System.
2.) FMC represents Flexible Membrane Cover.
3.) FSmin represents a minimum Factor of Safety.
4.) N/A indicates Not Applicable.
5.) * indicates that information regarding the tensile strength of the geonet was not readily available and analyses for settlement were not performed.
6.) ** indicates properties of Textured Gundline HD (40 mil) HDPE liner were used in analyses.
7.) *** indicates assumed friction angle of 25 degrees between geotextile and adjacent vegetative or soil barrier layer.
8.) **** indicates assumed friction angle of 9 degrees between geonet and geotextile or geomembrane.

designs A, B, C, D, E, and J. The maximum allowable slope for cap designs F and I is 1 vertical on 4.3 horizontal (23 percent) based on sliding of the geotextile filter fabric. Maximum allowable slopes for cap designs G and H are significantly less due to the low friction angle developed at the geotextile-/geonet interface. The maximum allowable slope for cap designs G and H is 1 vertical on 12.6 horizontal (8 percent) .

2.03.05 Recommended Cap System

Results of the HELP model analyses and analyses of the cap components were reviewed to develop a final cap system design. The cap systems were evaluated as follows:

Cap Design A

Cap design A meets the requirements of the New Jersey Administrative Code (NJAC). Initial HELP model analyses for cap design A indicate that approximately 14,300 gallons/year of precipitation is likely to percolate through the cover system and into the underlying waste. These analyses were performed for a total landfill area of 76 acres graded at three percent slopes. This represents a conservative estimate as portions of the landfill will be graded at slopes which promote a greater percentage of runoff and internal drainage. It is noted that cap design A includes two 6-inch bedding layers and a 36-inch soil barrier layer. This cap design requires significantly greater quantities of materials for cap construction than the other cap designs, which would likely result in a higher cost of cap construction. Traffic to the site may also be increased in order to deliver the additional quantities of materials.

The maximum allowable slope based on the cap component analyses for cap design A is 1 vertical on 6.5 horizontal (15 percent) if LDPE materials are used. These slopes do not differ significantly from those for the other cap designs.

Based on the increased quantities of materials required for construction of cap design A and its performance estimated by the HELP model analyses, cap design A is not recommended as a part of the final cap system.

Cap Design B

Cap design B meets the requirements of the NJAC. HELP model analyses performed for cap design B indicate that approximately 24,350 gallons/year of precipitation is likely to percolate through the cover system and into the underlying waste based on a landfill cap area of 76 acres graded at three percent slopes. An additional geomembrane and bedding layer is utilized in lieu of the soil barrier layer in cap design A. Although this design does not require a material which meets the requirements of the soil barrier layer, comparable quantities of bedding materials are required.

The maximum allowable slope based on the cap component analyses for cap design B is 1 vertical on 6.5 horizontal (15 percent) if LDPE materials are used. These slopes do not differ significantly from those for the other cap designs.

Based on the performance estimated by the HELP model analyses, cap design B is not recommended as part of the final cap system.

Cap Design C

Cap design C is in accordance with RCRA guidelines. Cap design C is estimated to allow approximately 25 gallons/year of precipitation to percolate through the waste layer based on a landfill cap area of 76 acres and slopes of three percent. It is noted that this estimate may represent the lower range of precipitation percolating through the waste layer as a result of the assumptions of the HELP model.

The maximum allowable slope based on the cap component analyses for cap design C is 1 vertical on 6.5 horizontal (15 percent) if LDPE materials are used. These slopes do not differ significantly from those for the other cap designs.

The gas venting layer is not required, as an active gas collection system is proposed for the site. The Record of Decision (ROD) requires that the landfill cap meet RCRA requirements. Minimum technology guidance for covers on hazardous waste landfills lists gas venting layers as an optional component of the cover system. Therefore, the cap system meets minimum technology guidance without the gas venting layer. In addition, the recommended alternative in the ROD included an active collection and treatment system for methane and any other landfill-generated gases. Therefore, cap design C is not recommended as part of the final cap system.

Cap Design D

Cap design D is in accordance with RCRA guideline and is estimated to allow approximately 6,034,500 gallons/year of precipitation to percolate through the waste layer based on a landfill cap area of 76 acres graded at three percent slopes. The maximum allowable slope based on the cap component analyses for cap design D is 1 vertical on 4.3.horizontal (23 percent). As discussed previously for cap design C, the installation of an active gas venting system is proposed at the site and the gas venting layer is not required. Therefore, cap design D is not recommended as part of the final cap system.

Cap Design E

Cap design E meets the RCRA guidelines and is identical to cap design C with the exception of the gas venting layer. HELP model analyses performed for cap design E indicate that approximately 60 gallons/year of precipitation will percolate through the waste layer based on a landfill cap area of 76 acres graded at three percent slopes. As previously discussed, this estimate may represent the lower range of precipitation percolating through the waste layer as a result of the assumptions of the HELP model.

The maximum allowable slope based on the cap component analyses for cap design E is 1 vertical on 6.5 horizontal (15 percent) if LDPE materials are used. These slopes do not differ significantly from those for the other cap designs.

Cap design E is recommended as part of the final cap system based on the limited amount of percolation into the waste layer. These slopes require the use of a textured HDPE material for the geomembrane. If an LDPE material is utilized, the maximum allowable slope is 1 vertical on 6.5.horizontal (15 percent).

Cap Design F

Cap design F is in accordance with RCRA guidelines. HELP models runs performed for cap design F estimate that 6,035,450 gallons/year of precipitation will percolate through the cap system based on a landfill cap area of 76 acres graded at three percent slopes. It is noted that cap design F does not incorporate a geomembrane and the maximum allowable slopes are 1 vertical on 4.3 horizontal (23 percent). Cap design F is recommended as part of the final cap system and is to be used in areas where the slopes are greater than 1 vertical on 6.5 horizontal (15 percent) if a LDPE material is utilized in cap design E. Cap F minimizes the amount of refuse to be relocated and volume of fill material required.

Cap Design G

Cap design G is in accordance with RCRA guidelines and differs from cap design E only in that a geosynthetic material is proposed for use as the drainage layer in lieu of a soil drainage layer. HELP model analyses performed for cap design G indicate that approximately eight gallons/year of precipitation will enter the waste layer based on a landfill cap area of 76 acres graded at three percent slopes. As previously discussed, this estimate may represent the lower range of precipitation percolating through the waste layer as a result of the assumptions of the HELP model.

The limiting parameter with respect to cap design G is that the maximum allowable slopes are approximately 1 vertical on 12.6 horizontal (8 percent). The maximum slopes are governed by the low friction angle between the geosynthetic drainage material and overlying geotextile. If cap design G were used as part of the final cap system, large quantities of fill materials would be required and large retaining structures would be required to limit the extent of the cap within appropriate distances from adjacent properties, right of ways, and environmentally sensitive areas. In addition, there has been limited experience with the long-term performance of geosynthetic drainage materials. Therefore, cap design G is not recommended as a portion of the final cap system.

Cap Design H

Cap design H is in accordance with RCRA requirements. HELP model analyses performed for cap design H indicate that approximately 876,600 gallons/year of precipitation will percolate through the cap system based on a landfill cap area of 76 acres graded at three percent slopes. Cap design H is similar to cap design G in that the limiting parameter is that the maximum allowable slopes are 1 vertical on 12.6 horizontal (8 percent). Based on the discussion for cap design G, cap design H is not recommended as a portion of the final cap system.

Cap Design I

Cap design I is estimated to allow approximately 4,776,350 gallons/year of precipitation to percolate through the cap system based on landfill cap area of 76 acres graded at three percent slopes. The maximum allowable slopes for cap design I are 1 vertical on 4.3 horizontal (23 percent). It is likely that this cap design will not be accepted as meeting the RCRA requirements. Therefore, cap design I is not recommended as a portion of the final cap system.

Cap Design J

Cap design J is estimated to allow approximately 57,800 gallons/year of precipitation to enter the waste layer based on a landfill cap area of 76 acres graded at 3 percent slopes. The maximum allowable slopes for cap design J are 1 vertical on 4.3 horizontal (23 percent). However, this design does not meet the minimum requirements of RCRA and it is unlikely that a design with this cap system would be acceptable. Therefore, cap design J is not recommended as a portion of the final cap system.

Based on results of the HELP model analyses and stability analyses for the cap components, cap designs E and F were selected. Cap designs E and F are in accordance with RCRA guidelines. Cap sections C and D are similar to cap sections E and F, respectively, with the exception that cap sections C and D utilize a one foot thick gas venting layer below the soil barrier layer. Results of the HELP model analyses indicate that the respective cap systems will perform in a similar manner relative to limiting infiltration. As previously discussed, a passive gas venting layer is not required. An active gas extraction and treatment system is proposed for the site. The Record of Decision (ROD) requires that the landfill cap meet RCRA requirements. The minimum technology guidance for covers on hazardous waste landfills lists gas venting layers as optional components of the cover system. Therefore, the cap system meets minimum technology guidance without the gas venting layer. The cover currently in place on the site appears to be permeable and capable of venting gas. In addition, the recommended alternative in the ROD includes an active gas extraction and treatment system for methane and any other landfill generated gases.

The entire area to be capped was modified to 65.2 acres based on results of the fill delineation program. During the initial analyses, the cap was assumed to extend over approximately 76 acres. As presented in the following section, the areal extent of Cap E is governed by the angle of internal friction of the smooth geomembrane against the adjacent soil barrier layer. Cap E should be installed in areas where slopes are 1 vertical on 6.5 horizontal (15 percent) or less to provide an adequate factor of safety against sliding of the cap components. Cap system F should be utilized over the remaining capped area, where the slopes will be regraded to a maximum of one vertical on 4.5 horizontal (22 percent).

2.03.06 Preliminary Cap Performance Analyses

Preliminary analyses were performed for cap systems E and F to estimate the volume of precipitation percolating through the selected cap systems based on the preliminary design and defined by the fill delineation area and geomembrane area. A parametric study was performed to evaluate the effect of varying liner leakage rates. Liner leakage fractions of 0.01 and 0.10 were utilized for cap system E. An additional analysis was performed using a liner leakage fraction of 0.00001 as used in the initial HELP model analyses.

Results of these analyses are summarized in Table 2-4. Computer outputs for the analyses are included in Appendix 2-4. Based on the results, it appears that the average yearly percolation into the waste layer may range from 3,071,000 to 3,239,000 gallons per year for liner leakage fraction rates of 0.00001 to 0.1 and where the geomembrane is placed in areas having slopes of seven percent or less, as originally directed by the New Jersey Department of Environmental Protection (NJDEP). Peak daily percolation may range from 10,300 to 10,800 gallons per day. A liner leakage fraction of 0.1 represents an upper limit for the analyses and assumes that for every 10 acres of geomembrane placed, there will be an effective defect area of one acre. This appears to be a highly unlikely case.

2.03.07 Final Cap Performance Analyses

Results of Final Cap Performance

A series of analyses incorporating modifications to the preliminary design were performed to evaluate cap designs E and F. These modifications included installation of the geomembrane FMC over areas of slopes of ten (10) percent and less only and utilization of a liner leakage fraction of 0.001

TABLE 2-4
Combe Fill South Landfill Remediation Program
Morris County, New Jersey

PRELIMINARY HELP MODEL (VERSION 2) RESULTS

Cap System	Area (Acres)	Liner Leakage Fraction	Average Yearly Percolation Into Waste Layer (Gallons/Year)	Peak Daily Percolation Into Waste Layer (Gallons/Day)
E	21	0.00001	15*	0*
E	21	0.01	16,800	50
E	21	0.1	168,000	500
F	44.2	N/A	3,071,200	10,260

N/A indicates Not/Applicable as cap design F does not incorporate a geomembrane.

* indicates that this value may represent a lower limit of volume of precipitation estimated to percolate into the waste layer due to assumptions made in the HELP model.

both as recommended by the New Jersey Department of Environmental Protection (NJDEP) and the Bureau of Solid Waste (BSW). Based on recommendations by the NJDEP, a 40 mil FMC is to be placed in areas with slopes up to 10 percent. Therefore, the extent of cap systems E was increased to 26.5 acres and cap system F was decreased to 38.7 acres. In addition, subsurface drainage laterals spaced a 170 feet were incorporated in the analyses.

Results of the analyses corresponding to the final design are presented in Table 2-5. Computer outputs for the analyses are included in Appendix 2-5.

Minimization of Maintenance

As discussed under the vegetative cover section of Section 2.03.01, the species selected for the vegetative cover will be adapted to the climate of the region, be relatively quick growing, shallow rooted, able to grow year round, be self propogating, and require a minimum amount of short and long term maintenance. The seed mixture will consist of Tall Fescue, Spreading Fescue, and Kentucky Bluegrass. The vegetative cover will require minimum maintenance and will prevent erosion.

Promotion of Drainage and Minimization of Erosion or Abrasion

The recommended cap systems for the Combe Fill South Landfill are designed with maximum slopes of one vertical on 4.5 horizontal (22 percent), and minimum slopes of 4 vertical on 100 horizontal (4 percent). The four

TABLE 2-5
Combe Fill South Landfill Remediation Program
Morris County, New Jersey

FINAL HELP MODEL (VERSION 2) RESULTS

Cap System	Area (Acres)	Liner Leakage Fraction	Average Yearly Percolation Into Waste Layer (Gallons/Year)	Peak Daily Percolation Into Waste Layer (Gallons/Day)
E	26.5	0.001	1,360	6
F	38.7	N/A	1,354,600	6,343

N/A indicates Not/Applicable as cap design F does not incorporate a geomembrane.

percent slope exceeds EPA technical guidance documents requiring a minimum slope of 3 vertical on 100 horizontal (3 percent). The maximum sideslopes of 1 vertical on 4.5 horizontal (22 percent) are less steep than sideslopes of 1 vertical on 4 horizontal (25 percent) which have been successfully utilized at other EPA approved sites without evidence of soil erosion. By virtue of the technical guidance documents, EPA indicates that a three percent slope is considered suitable to promote runoff. Since the maximum sideslope is greater, it too will promote runoff.

As discussed above, once the vegetative cover is established, it will serve to inhibit erosion. Surface water drainage diversion ditches will be installed at 15 foot changes in elevation to minimize erosion. During the period in which vegetation is becoming established on the cap, protection against wash-out and erosion will be provided using soil stabilization techniques. These techniques may include jute mesh, a synthetic stabilization mat or other means. Temporary silt dams will be installed in ditches to prevent the removal of soil from the site by erosion during the period in which vegetation is becoming established. Once the vegetation is established, the cap will be sufficiently protected against erosion.

Accommodation of Subsidence

As previously discussed, it is difficult to estimate landfill settlement. The analysis described in Section 2.03.01 estimates total settlement to be on the order of 3.5 feet. This represents a conservative estimate of the settlement likely to occur. Recognizing that landfill has been closed since

1981 and that a great majority of the predicted settlement has most likely occurred within the past nine years, differential settlement is anticipated to be minimal. Therefore, settlement should have no appreciable effect on the completed cover.

Cover Permeability versus Underlying Permeability

According to information presented in the RI/FS, the range of calculated hydraulic conductivity for the saprolite beneath the landfill is estimated to be approximately 2×10^{-3} cm/sec based on wells screened in this strata.

The permeability of the cover is controlled by the least permeable layer. Cap design E utilizes a geomembrane as a barrier layer. Hydraulic conductivities for geomembranes are typically reported as being less than 1×10^{-12} cm/sec. Cap design F utilizes a soil barrier layer with a minimum hydraulic conductivity of 1×10^{-7} cm/sec. Therefore, the cap systems meet the requirement of having a hydraulic conductivity less than that of the underlying soils.

Ability to Repair

The regulations require that covers be designed so as to be repairable to correct settling, subsidence, erosion, etc. As documented elsewhere in this section, settlement and subsidence are anticipated to be minimal, and all cap alternatives are designed so as to minimize the effects of erosion. Should damage be caused by any of these occurrences, the damaged area will be repairable using conventional construction techniques.

2.03.08 Foundation and Slope Stability Analyses

A series of analyses were performed to evaluate the foundation stability and slope stability of the Combe Fill South Landfill. The foundation stability analyses were performed to evaluate the stability of the loaded foundation beneath the existing landfill. An analysis of the slope stability was performed to evaluate the ability of the landfill slopes to remain stable when placed at the proposed final grades. The analyses were based on the preliminary design and information obtained during field investigations.

The maximum slopes for the initial analyses were estimated to be approximately 1 vertical on 6.3 horizontal. Construction of the cap at these slopes would require the relocation of large quantities of refuse. As a result of modifications to the preliminary grading plan, an additional series of analyses were performed to evaluate stability of the landfill with respect to the more steeply graded slopes. The preliminary grading plan was modified to maximum slopes of 1 vertical on 4.5 horizontal based on stability of the cap components and minimization of refuse relocation.

Subsurface Conditions

The surficial materials at the Combe Fill South site consist, from the surface down, of fill, natural soils, saprolite and granite bedrock. Beneath the fill, the natural soils consist of clay, silt, sand and gravel. Materials encountered during drilling range from silty clay to silty sand, and are approximately 0 to 50 ft thick. Beneath these natural soils is granitic saprolite, derived from the weathering of bedrock. The saprolite consists of silt, sand, and weathered granite fragments, and ranges in thickness from approximately 10 to 45 ft across the site. Bedrock at the landfill is a hornblende granite containing predominantly quartz, feldspar and hornblende according to Lawler, Matusky, and Skelly Engineers in the Final Conceptual Design Report dated June, 1987.

Soil Properties

In order to analyze the stability of the proposed landfill, it was necessary to ascertain the structural properties of soils likely to be used in the construction of the landfill cap and of soils present at the site. The initial series of analyses were performed based on the cap design presented in the Final Conceptual Design Report by Lawler, Matusky, and Skelly Engineers. The proposed cap design consists of the following starting from the ground surface:

- 6 inch topsoil layer
- 18 inch vegetative layer
- geotextile filter
- 12 inch sand layer (drainage layer)
- geomembrane
- 24 inch clay layer (soil barrier layer)
- geotextile filter

- 12 inch gravel layer (gas venting layer)

For purposes of the analyses, the landfill cap was modeled as two layers, one including the topsoil, embankment material, geotextile, sand, and geomembrane layers and the second including the clay layer. The conservative assumption was made to model the gravel gas venting layer as part of the underlying waste layer. It is noted that this cap design corresponds to the final cap designs recommended for the landfill, with the exception of the gas venting layer. The final cap design incorporates an active gas venting system, and, therefore, the use of a gas venting layer in the cap system is not recommended. Remaining layers were taken as the waste layer, the underlying silt layer, and the saprolite layer overlying the granite bedrock.

The soil properties required for the analyses include soil cohesion, angle of internal friction, and the in-situ unit weight. Initial values of soil properties used for the initial analyses were modified as noted in the following discussion for the final stability analyses. Soil properties used for the initial analyses and the corresponding results are included as Appendix 2-6. Table 2-6 summarizes the soil properties utilized for each soil layer for the final series of analyses. The bases for selecting soil properties were established as follows for each soil layer:

Cohesion

Where utilized, the cohesive strength was taken to be the undrained shear strength. In order to be conservative, no cohesive strength was assigned to the cap layer representing the topsoil, embankment material,

TABLE 2-6

SOIL PARAMETERS USED AS INPUT FOR
FOUNDATION AND SLOPE STABILITY ANALYSES

COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY

LAYER	COHESIVE STRENGTH (psf)	ANGLE OF INTERNAL FRICTION (degrees)	UNIT WEIGHT (pcf)
Topsoil, local borrow, geotextile, sand, and geomembrane components of proposed cap	0	17	110
Soil barrier layer component of cap	1500	0	120
* Waste	500 1000	0 0	40 90
Silt Layer	1000	0	120
Saprolite Layer	1000	0	120
Granite Bedrock	0	40	160

NOTES:
1.) * indicates that analyses were performed with varying parameters to assess their influence on the minimum calculated factor of safety.

geotextile, sand, and geomembrane layers. The soil barrier layer was assigned a cohesive strength of 1500 pounds per square foot (psf). Analyses were performed with values of 500 and 1000 psf for the waste layer to represent a range of cohesive strengths corresponding to the range of typical refuse densities. A cohesive strength of 1000 psf was assigned to the silt and saprolite layers. The conservative assumption was made that the bedrock has no cohesive strength.

A value of 1500 psf was selected for the soil barrier layer component of the cap. Results of the unconsolidated, undrained triaxial tests for materials likely to be used in construction of the soil barrier layer indicated that the soils had shear strengths ranging from approximately 1700 to 2200 psf.

The cohesive strengths used for the waste layer were selected to represent a range of cohesive strengths corresponding to the range of typical waste densities. According to the Handbook of Solid Waste Management (Wilson, 1977), residential waste may have densities ranging from 89 to 750 pounds per cubic yard (3.3 to 27.8 pcf) while industrial waste, excluding heavy metal scrap, may have densities ranging from 50 to 2430 pounds per cubic yard (1.9 to 90 pcf). It is noted that both industrial and residential wastes were accepted at the Combe Fill South landfill. A representative value of 1,100 pounds per cubic yard (40 pcf) was taken as an average value for material deposited at Combe Fill South Landfill. Preliminary analyses were performed with unit weights of 40 and 120 pcf to assess the stability of the fill with various unit weights. A unit weight of 120 pcf represents a conservatively high value for heavy metal scrap. There is no indication that heavy metal scrap is buried near the critical cross-section, nor that it is concentrated in any one place on site, thus raising the unit weight of a given area. It is more likely that the average unit weight is near 40 pcf. The final stability analyses were performed with unit weights of 40 and 90 pcf. A unit weight of 90 pcf corresponds to the upper range of densities for industrial waste excluding heavy metal scrap. The cohesive strength of 500 psf is assumed to correspond to a typical unit weight of 40 pcf. According to Terzaghi and Peck (1967), a cohesive strength of 500 psf corresponds to a material of soft consistency. Analyses were performed with a value of 1000 psf for the waste layer where unit weights of 90 and 120 pcf were assumed, to assess the stability with a fill of heavier unit weight. A cohesive strength of 1000 psf corresponds to a material of medium consistency. The increased strengths were selected to reflect that as unit weight and soil density increase, soil strength generally increases (NAVFAC, 1982).

The cohesive strengths utilized for the underlying silt layer and saprolite layer were selected based on blow counts from the Standard Penetration Tests (SPT) conducted during the installation of test borings for the remedial investigation/feasibility study and installation of pump test and pump test observation wells. Boring logs for the soil borings are included in Appendix 2-8.

The lowest blow counts (N value) for the silt layer were 2 and 3 at depths of 10 to 12 feet below ground surface in borings PTO-5 and PTO-6, respectively. The next lowest N value for the silt layer was 7 within the uppermost two feet of boring SB-4. It is noted, however, that the majority of the N values for the silt layer were in excess of 15 and ranged up to 100 (0.5). Based on this information, the soil cohesive strength was estimated based on the N value of 7. According to Terzaghi and Peck (1967), a N value of 7 indicates a soil of medium consistency with unconfined compressive strengths ranging from 1,000 to 2,000 psf. These unconfined compressive strengths represent cohesive strengths of 500 to 1,000 psf. It is noted that a value of 1,000 psf corresponding to the minimum N value of 7 for the silt layer represents a conservative estimate of the cohesive strength. As previously discussed, the majority of the N values for the silt layer exceed 15, which corresponds to a cohesive strength of approximately 2,000 psf.

The lowest blow count for the saprolite layer was 11 at a depth of approximately 40 feet below ground surface in boring SB-2. A N value of 11 indicates a soil of stiff consistency with unconfined compressive strengths ranging from 2,000 to 4,000 psf. These unconfined compressive strengths correspond to cohesive strengths of 1,000 to 2,000 psf. In order to be conservative, a value of 1,000 psf, representing the lower value of the range, was assigned to the saprolite layer.

Angle of Internal Friction

The angle of internal friction utilized for the topsoil, embankment material, geotextile, sand and geomembrane layer was selected to represent the minimum angle of internal friction between adjacent interfaces of the cap components. It is likely that the angle of internal friction for the uppermost components of the cap system will be governed by the angle of internal friction at the sand/geomembrane or geomembrane/soil barrier layer interface.

The layer representing the topsoil, vegetative layer material, geotextile, sand, and geomembrane layers was modeled with a friction angle of 17 degrees. Recognizing that the soils used in the cap will include soils whose strengths are being omitted, and that the tensile strength of the geotextile and geomembrane is being ignored, it can be seen that use of 17 degrees is conservative.

Strength contributions due to friction were ignored in the layer representing the clay layer. Similarly, the silt and saprolite layers were assigned cohesive strengths only. Several initial analyses were performed where the waste layer was assigned an angle of internal friction of 14 degrees. This value is based on the steepest slope at which the existing refuse is presently graded. The waste layer was not assigned an angle of the internal friction during final analyses. It is anticipated that analyses performed with the strength of the waste characterized by its cohesive strength only are more conservative. The granite bedrock was assigned an angle of internal friction of 40 degrees. This value is based on typical values for granite given by Goodman (1980).

Unit Weight

The unit weight of the layer representing the topsoil, local borrow, geotextile, sand, and geomembrane layers was taken as 110 pcf. The layer representing the clay layer was assigned a value of 120 pcf. Results of laboratory analyses for soils likely to be used in construction of the soil barrier layer indicated that the unit weights for the materials compacted in accordance with the 15 blow modification to ASTM D-698 (Standard Proctor) were generally less than 120 pcf. Samples obtained from McNear Excavating and Piocosta Sand and Gravel showed unit weights greater than 120 pcf and ranged from approximately 131 to 136 pcf. It is noted that the McNear sample was prepared in accordance with ASTM D-1557 Method C (Modified Proctor).

As previously discussed, initial analyses were performed with unit weights of 40 and 120 pcf to evaluate the foundation and slope stability with a range of unit weights. The final analyses were performed with unit weights of 40 and 90 pcf. Unit weights of the silt and saprolite layers were taken to be 120 pcf. A value of 160 pcf was assigned to the granite bedrock according to typical values presented by Goodman (1980).

<u>Method of Analysis</u>

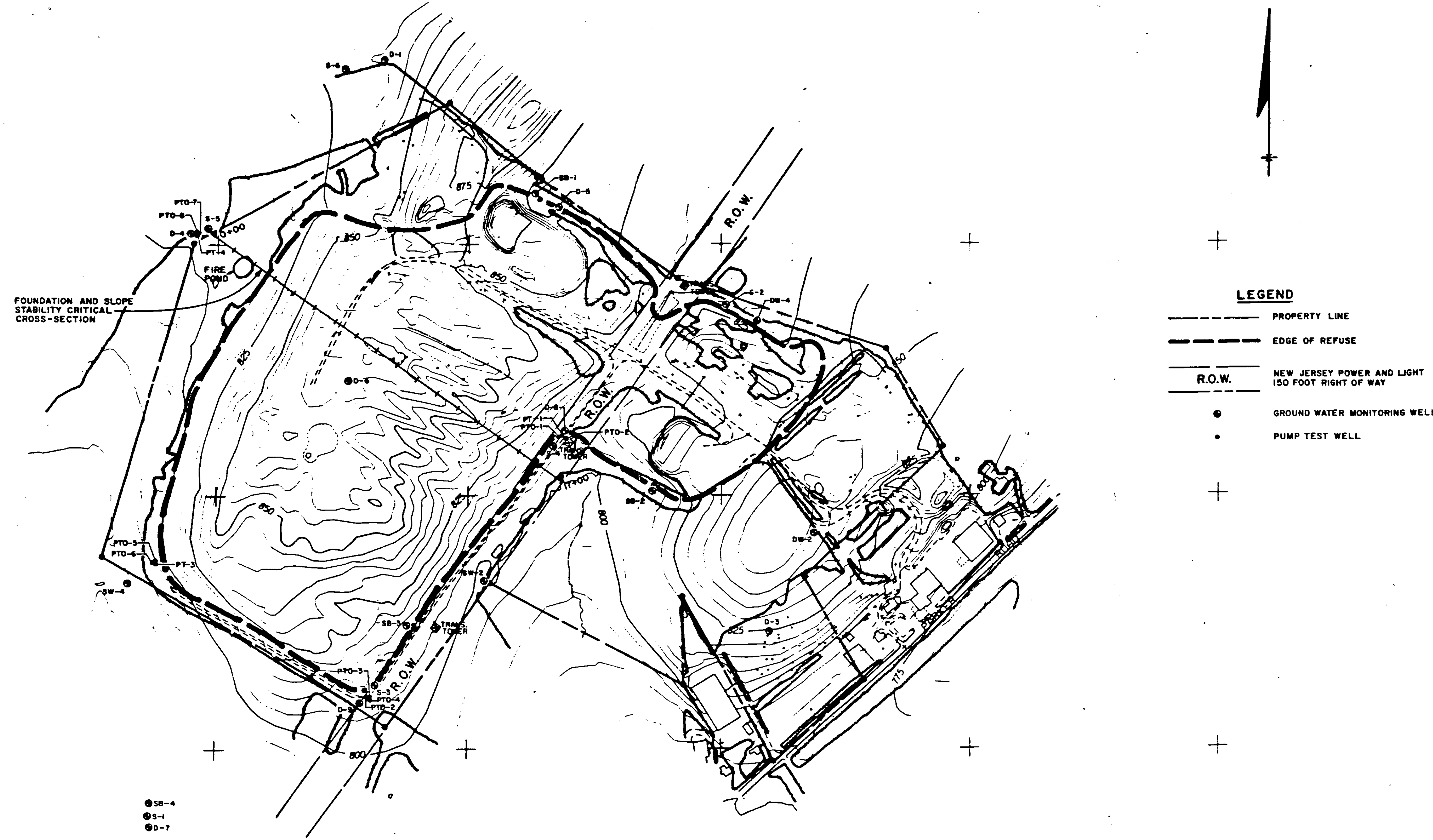
In order to conduct a computer analysis of the stability of the completed landfill, the computer program titled "STABR", developed by J.M. Duncan and Kai Sin Wong (1985) was utilized. The program calculates factors of safety for a given set of conditions using Bishop's Modified Method. A detailed discussion of this method may be found in Winterkorn and Fang (1975).

Inputs to the program include information regarding areas to be searched, the geometry (slopes, number of sections to be analyzed, number of soil layers, the presence or absence of tension cracks, and the presence or absence of water in the tension cracks), seismic coefficients, and soil properties.

Foundation and slope stability analyses were performed for the Combe Fill South landfill site. The foundation stability analyses were performed to evaluate the stability of the loaded foundation beneath the existing foundation. An analysis of the slope stability was performed to evaluate the ability of the landfill slopes to remain stable when placed at the proposed final grades. Figure 2-6 shows the location of the critical cross-section used for the analyses. This location was chosen because the slope rises the most steeply over the longest distance at this location. The maximum slope of the section is 1 vertical on 4.5 horizontal. This slope was chosen based on stability analyses of the cap components.

Figure 2-7 shows the critical cross-section. The cross-section was developed based on information presented in the remedial investigation/feasibility study and soil borings performed during the installation of the pump test and pump test observation wells. The cross-section shows that the landfill is underlain predominantly by a saprolite layer eight to 25 feet thick overlying granite bedrock. A 15 to 25 foot thick silt layer overlies the saprolite layer in areas northwest and southeast of the fill area at the critical cross-section.

FIGURE 2-6



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Made by ______			

O'BRIEN & GERE ENGINEERS, INC.
Syracuse New York

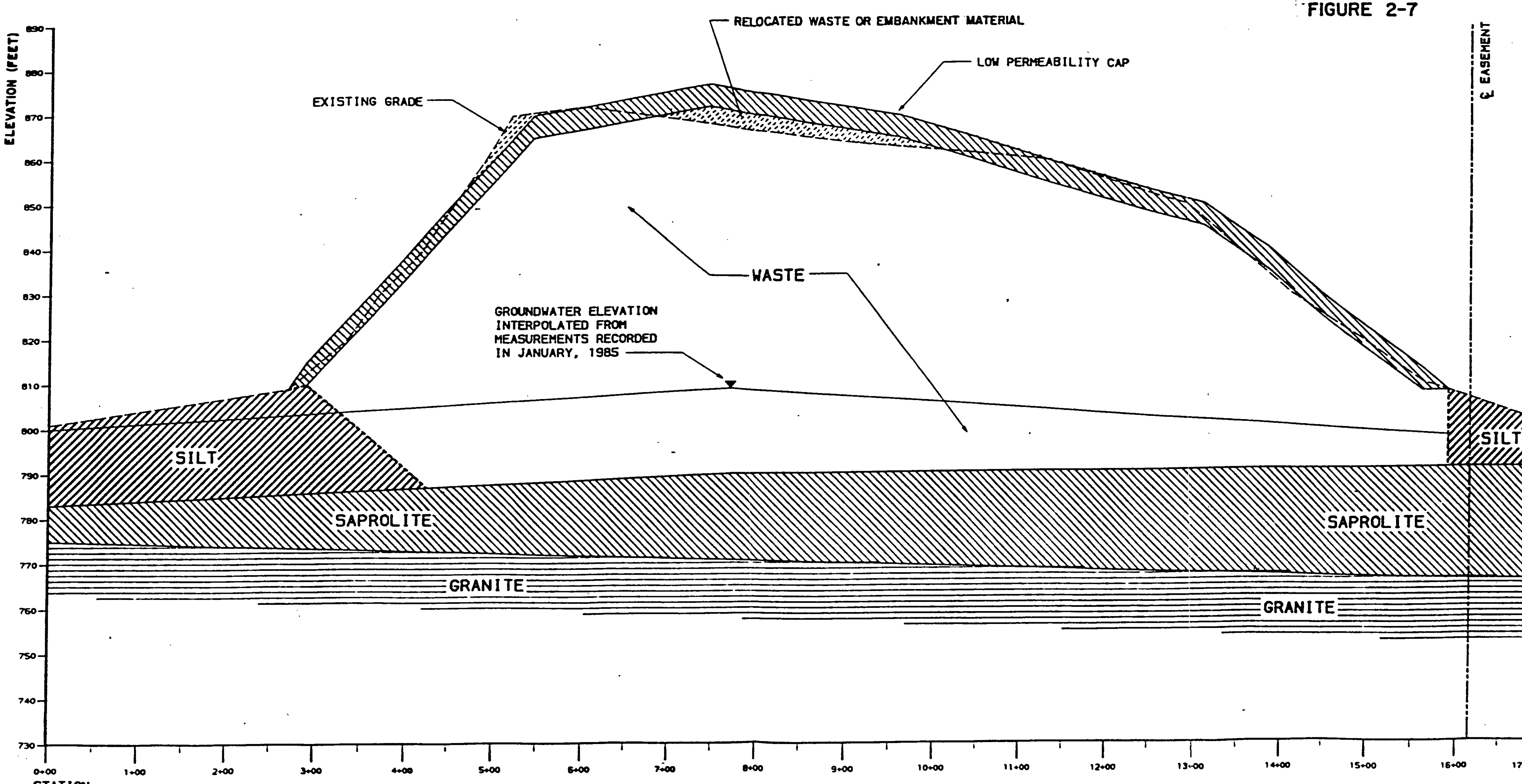
COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

LOCATION OF FOUNDATION AND SLOPE STABILITY CRITICAL CROSS-SECTION

FILE NO 3013.012-
DATE MAY, 1989

FIG. 2-6

FIGURE 2-7



COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
FOUNDATION & SLOPE STABILITY ANALYSIS CRITICAL CROSS-SECTION

Ground water in the area of the existing landfill was modeled at the depths measured in January, 1985. Corresponding ground water elevations measured from August, 1988 to January, 1989 were also reviewed and found to correspond to those measured in January, 1985.

Foundation Stability

For the conditions present at the site, the failure of the landfill foundation will likely take the form of a circle passing through the slope and foundation, tangent to a relatively strong layer. Consequently, analyses were performed with circular slip surfaces tangent to the soil and rock layers underlying the waste layer. Initial analyses were performed with the circular slip surface tangent to the base of the waste, silt, saprolite, and granite bedrock layers. It is noted that the depths to the base of the waste layer and surface of the silt layer were estimated from information available in the soil boring logs. Based on information available at that time, two average depths were used to characterize the base of the waste layer and surface of the silt layer. The final analyses were performed with the circular slope surfaces tangent to the surfaces of the silt, saprolite and granite bedrock layers. Estimates regarding the average depth to the surface of the silt layer were modified and an average depth was selected to characterize the location of the silt/waste layer interface.

TABLE 2-7
RESULTS OF FOUNDATION STABILITY ANALYSES - STATIC CONDITIONS

COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY

Layer Tangent to Failure Surface	Waste Cohesive Strength (psf)	Unit Weight of Waste (pcf)	Minimum Calculated Factor of Safety
Silt Layer	500	40	2.42
Silt Layer	1000	90	1.80
Saprolite Layer	500	40	2.48
Saprolite Layer	1000	90	1.49
Granite Bedrock	500	40	3.75
Granite Bedrock	1000	90	2.31

TABLE 2-8
RESULTS OF SLOPE STABILITY ANALYSES - STATIC CONDITIONS

COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY

Type of Assumed Failure	Waste Cohesive Strength (psf)	Unit Weight of Waste (pcf)	Minimum Calculated Factor of Safety
Toe Failure	500	40	2.10
Toe Failure	1000	90	1.50

Slope Stability

Slope failure at this site would likely take the form of a rotational failure in close proximity to the toe of the landfill. This situation was modeled in these analyses.

2.03.09 Results of Foundation and Slope Stability Analyses

Soil parameters used as input for the final foundation and slope stability analyses are summarized in Table 2-6 (previously presented). Tables 2-7 and 2-8 present results of the foundation and slope stability analyses under static conditions for the final stability analyses. Detailed computer outputs for the analyses are included in Appendix 2-7.

Table 1 in Appendix 2-6 summarizes the soil parameters used as input for the initial stability analyses. Results of foundation and slope stability analyses under static conditions are presented in Tables 2 and 3 of Appendix 2-6, respectively. Detailed computer outputs for the initial analyses are also included in Appendix 2-6.

The computed factors of safety were compared with the following factors of safety as given in Section 7:26-2A79b)(3)(i) of the New Jersey Administrative Code:

Measurement Factor of Safety	Degree of Uncertainty of Strength	
	Low	High
Static Conditions	1.5	2.0
Seismic Conditions	1.3	1.7

In addition, the following recommended factors of safety are noted as provided in the "Permit Applicants Guidance Manual for hazardous Waste Land Treatment" by the USEPA. These criteria are as follows:

RECOMMENDED MINIMUM VALUES OF FACTOR OF SAFETY FOR SLOPE STABILITY ANALYSES

Consequences of Slope Failure	Uncertainty of Strength Measurements	
	Small	Large
No imminent danger to human life or major environmental impact if slope fails	1.25 (1.2)	1.5 (1.3)
Imminent danger to human life or major environmental impact if slope fails	1.5 (1.3)	2.0 (1.7 or greater)

NOTE: Numbers in parentheses apply when seismic activity has been taken into account.

The NJDEP advised O'Brien & Gere that the design factor of safety for the landfill slopes should be 1.5 for static conditions and 1.3 for seismic conditions.

Foundation Stability Results

Results of the final foundation stability analyses under static conditions, shown in Table 2-7 (previously presented), indicate minimum calculated factors of safety greater than 1.5 for the conditions analyzed with the exception of one case. The circular slip surface assumed tangent to the saprolite layer and the waste layer was assumed to have a unit weight of 90 pcf for the case where the factor of safety was estimated to be 1.49. As previously discussed, a unit weight of 90 pcf corresponds to the upper range of densities for industrial waste excluding heavy metal scrap. It is noted that the minimum calculated factor of safety for this case is approximately equal to 1.5. In addition, the soil parameters utilized for the analyses represent conservative values.

Results of the foundation stability analyses under static conditions for the initial analyses indicate that the calculated minimum factors of safety were greater than 1.5 for the conditions modeled with the exception of two cases. These cases assumed that the failure of the landfill foundation would likely take the form of a circle passing through the slope and foundation, tangent to the granite bedrock and that the waste would have a unit weight of 120 pounds per cubic foot (pcf). In one of the cases, the waste was assumed to have a cohesive strength of 1,000 psf. The waste was assumed to have an angle of internal friction of 14 degrees for the second case. The calculated minimum factors of safety for these cases were 1.33 and 1.34, respectively. As previously discussed, all other analyses performed with the circular slip surface tangent to the waste, silt, saprolite, and granite bedrock layers showed minimum factors of safety greater than 1.5.

The analyses performed with an assumed unit weight of 120 pcf and failure surface assumed tangent to the granite bedrock layer represent extremely conservative approaches. Analyses were performed with a unit weight of 120 pcf to assess the stability with a fill of heavier unit weight. As previously discussed, a unit weight of 120 pcf represents a conservatively high value for heavy metal scrap. There is no indication that heavy metal scrap is buried near the critical cross section, nor that it is concentrated in any one place on site, thus raising the unit weight of a given area. The average unit weight is most likely near 40 pcf.

It is most likely that a foundation failure would occur at a relatively weak/strong soil layer interface. In this case, it is anticipated that the waste layer/silt layer interface is the interface through which a failure is most likely to occur. In summary, the two cases of preliminary stability analyses where the calculated minimum factors of safety were less than 1.5 represent extremely conservative approaches. It appears that these cases model a mode of failure which is less likely to occur than a potential failure along the waste layer/silt layer interface. In addition, the existing slopes of the landfill have been and continue to be stable at maximum grades of approximately 1 vertical on 3.5 horizontal. Maximum slopes of 1 vertical on 3 horizontal are acceptable, according to New Jersey Administrative Code Section 7:26-2A.8(b)(5). Therefore, the cases analyzed with conservative assumptions for foundation stability represent factors of safety less than 1.5, the results of the remaining analyses indicate the the calculated minimum factors of safety are suitable for foundation and slope stability. The cases with factors of safety in excess of 1.5 represent the most likely modes of failure and the most typical refuse properties.

Slope Stability Results

Table 2-8 (previously presented) summarizes the results for the final slope stability analyses. The minimum calculated factors of safety were equal to or greater than 1.5 and ranged from 1.50 to 2.10 for the conditions analyzed.

These factors of safety are less than those calculated for the initial slope stability analyses. This can be attributed to modifications as the design progressed in the grading plan from maximum slopes of 1 vertical on 6.3 horizontal to 1 vertical on 4.5 horizontal.

Results of the initial slope stability analyses indicated that the minimum calculated factors of safety were greater than 1.5 for the conditions analyzed. The minimum calculated factors of safety ranged from 2.84 to 6.07.

Seismic Analyses

By the exclusion of New Jersey from 40 CFR Part 264, Appendix VI, the Environmental Protection Agency indicates that there are no faults present in New Jersey which have seen displacement since Holocene times. As stated in the comment of 40 CFR 270.14(g)(11) no further information is required to demonstrate compliance with 40 CFR 264.18(a). However, analyses were performed based on the preliminary grading plan with maximum slopes of 1 vertical on 4.5 horizontal to determine the effects of earthquake accelerations upon the completed landfill. The results of the analyses are summarized in Tables 2-9 and 2-10.

Results of the analyses indicate that the landfill could withstand earthquake accelerations ranging from 0.02g to 0.20g and still maintain acceptable factors of safety for the conditions modelled for the foundation analyses. Analyses further indicate that the landfill could withstand earthquake accelerations ranging from 0.03g to 0.13g and maintain factors of safety of 1.3 for the conditions modelled for the slope stability analyses.

TABLE 2-9
RESULTS OF FOUNDATION STABILITY ANALYSES - SEISMIC CONDITIONS

COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY

Layer Tangent to Failure Surface	Waste Cohesive Strength (psf)	Unit Weight of Waste (pcf)	Minimum Calculated Factor of Safety	Earthquake Acceleration
Silt Layer	500	40	1.32	0.14g
Silt Layer	1000	90	1.34	0.07g
Saprolite Layer	500	40	1.30	0.12g
Saprolite Layer	1000	90	1.35	0.02g
Granite Layer	500	40	1.32	0.20g
Granite Layer	1000	90	1.32	0.13g

TABLE 2-10

RESULTS OF SLOPE STABILITY ANALYSES - SEISMIC CONDITIONS

COMBE FILL SOUTH LANDFILL

MORRIS COUNTY, NEW JERSEY

Type of Assumed Failure	Waste Cohesive Strength (psf)	Unit Weight of Waste (pcf)	Minimum Calculated Factor of Safety	Earthquake Acceleration
Toe Failure	500	40	1.30	0.13g
Toe Failure	1000	90	1.31	0.03g

Summary

The New Jersey Administrative Code Section 7:26-2A.79b) (3)(i) indicates that the required factors of safety for foundation and slope stability for static and dynamic conditions are 1.5 and 1.3 for cases where the degree of uncertainty of the strength measurements are relatively low.

Although exclusion of New Jersey from 40 CFR Part 264 Appendix VI indicates that there are no faults present in New Jersey which have seen displacement since Holocene times and no further information is required to demonstrate compliance with 40 CFR 264.18(a), additional analyses were performed to evaluate the earthquake accelerations the completed landfill could withstand and still maintain suitable factors of safety. Based on the results of the analyses for the conditions modelled, the completed landfill may withstand earthquake accelerations from 0.02g to 0.20g for a factor of safety of approximately 1.3.

2.03.10 Materials Investigation

The components of the closure for the Combe Fill South Landfill will utilize a variety of materials, including geosynthetic materials and natural soil materials to be used in the construction of roads, the gas venting system, and cap system. In order to evaluate the natural soil materials to be used in the remedial program, a materials evaluation program was developed as presented in the Field Sampling and Testing Program (FSTP) Report. The following sections provide a summary of the sources and types of materials collected and evaluated for the Combe Fill South Landfill remedial program.

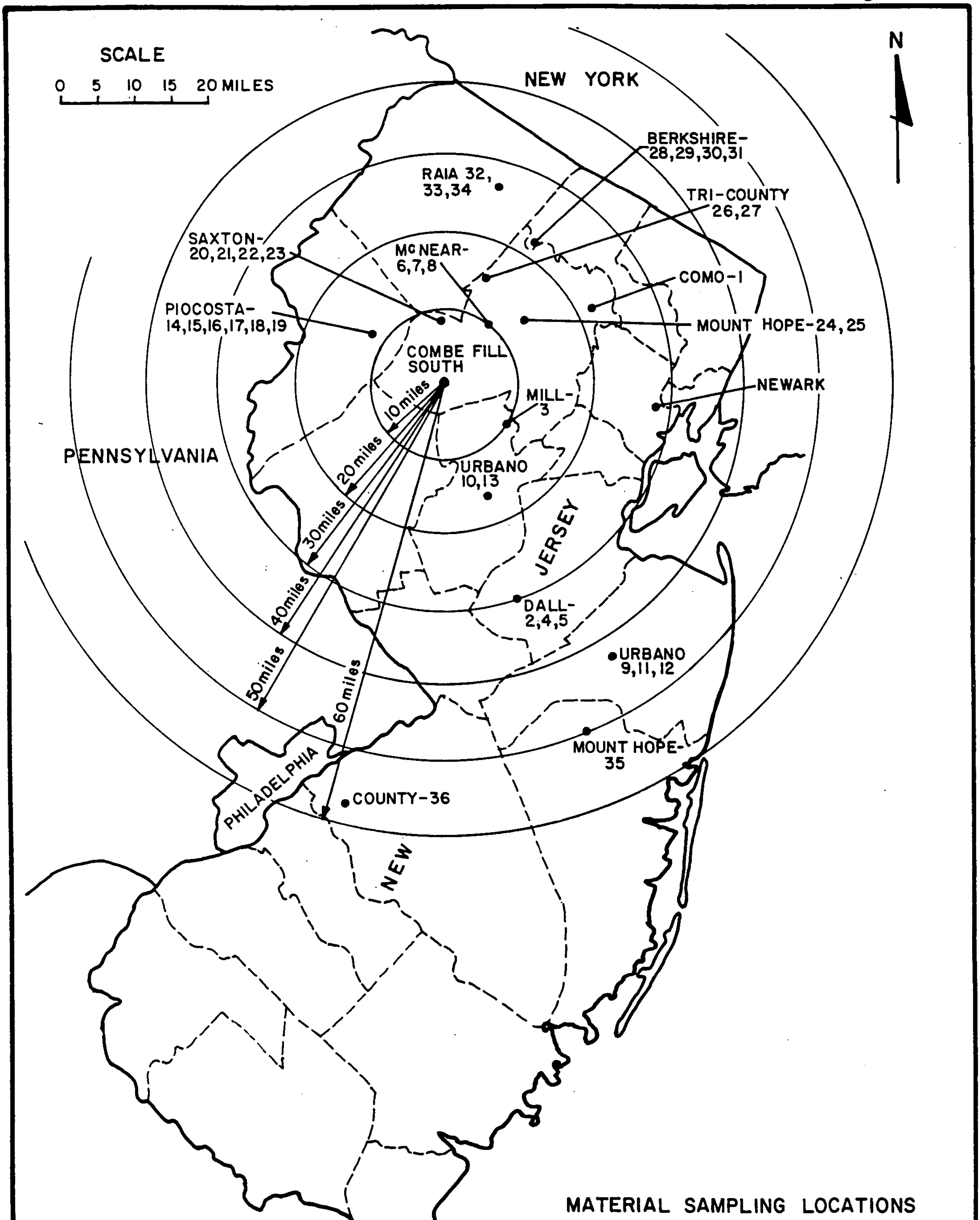
Soil Materials

As part of the materials evaluation program, a review of the availability of natural materials likely to be used during construction of the Combe Fill South site remedial program was conducted. The United States Department of Agriculture Soil Conservation Service and operators of local borrow areas and quarries were contacted. Following this review, several sites were selected for purposes of collecting samples of the materials.

A total of 11 potential sources of materials were visited during the week of January 9, 1989. Figure 2-8 shows the sampling locations. Table 2-11 presents a summary of the samples collected and the respective sources. During that week, 34 samples of materials likely to be used during implementation of the Combe Fill South Remedial program were collected. Multiple samples were collected from several of the potential sources. Two additional samples were collected on February 3, 1989. As discussed in the FSTP, up to five potential borrow sources for granular materials, five potential borrow sources for low permeability material, and three potential sources of topsoil were to be identified. Table 2-11 indicates that a total of ten potential sources of granular materials, eight potential sources of low permeability material, and four potential sources of topsoil were identified.

Samples were selected for laboratory analyses according to suitability for intended purpose based on visual observations, quantity of material available, quoted delivered cost, and proximity to the landfill site. Five granular materials, five samples of low permeability materials, and three topsoil samples were submitted for laboratory testing in accordance with the FSTP. Laboratory

Figure 2-8



NOTE:
SAMPLE NUMBERS CORRESPOND TO THOSE LISTED IN TABLE 2-11.

MATERIAL SAMPLING LOCATIONS

COMBE FILL SOUTH LANDFILL SUPERFUND SITE

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

MAY, 1989

O'BRIEN & GERE

TABLE 2-11
COMBE FILL SOUTH MATERIALS EVALUATION

Source	Date Sampled	Sample Number	Sample Description	Intended Use of Material	Remarks
Dallenbach Sand Co., Box 333 Dayton, NJ 08810 (201)-297-3381	1/10/89	2 4 5	Clay ** Concrete Sand ** Masonry Sand **	Low Permeability Material Drainage Layer Material Drainage Layer Material	Clay is material obtained during wet mine operation. As a result, material availability is dependent on dredging process and time required for material to dry.
Millington Quarry, Inc. Stonehouse Road P.O. Box 407 Millington, NJ 07946 (201)-580-3910	1/10/89	3	3/4 inch crushed stone	Gas Venting Layer, Roads	Crushed rock materials obtained from quarry in Wharton, NJ.
Dan Como & Sons (201)-263-0440	1/10/89	1	Screened Topsoil	Topsoil	
McNear Excavating Box M503 Landing, NJ 07850 (201)-398-9232	1/10/89	6 7 8	Common Fill ** Common Fill ** 3/4 inch crushed stone	Low Permeability Material Low Permeability Material Drainage Layer Material	Note that samples 6 and 7 are of the same material. However, these materials appear to differ significantly in gradation. Sample 6 represents the more predominant coarse fraction of the material, whereas sample 7 was collected from a limited area where soils were composed of a larger fraction of fine materials.

NOTES:
1. ** indicates that potential supplier provided results of laboratory analyses performed for samples obtained from source indicated. However, these analyses were not performed as part of this investigation.

TABLE 2-11 (CONTINUED)
COMBE FILL SOUTH MATERIALS EVALUATION

Source	Date Sampled	Sample Number	Sample Description	Intended Use of Material	Remarks
Tri-County Asphalt, Corp. Lake Hopatcong, NJ (201)-663-2010	1/11/89	26 27	3/4 inch crushed stone 1.5 inch crushed stone	Gas Venting Layer, Roads Gas Venting Layer, Roads	
Berkshire Valley Sand and Gravel Berkshire Valley Road Oak Ridge, NJ (201)-697-4800	1/12/89	28 29 30 31	Concrete Sand 3/4 inch gravel (rounded) 3/4 inch crushed rock "Clay" material	Drainage Layer Material Gas Venting Layer, Roads Gas Venting Layer, Roads Low Permeability Material	To provide sample of topsoil.
Raia Industries, Inc. Hamburg, NJ (site) (201)-488-0500	1/12/89	32 33 34	Minus 3/8 inch Sand Fill 3/4 in. crushed stone Concrete Sand	Drainage Layer Material Gas Venting Layer, Roads Drainage Layer Material	
County Sand & Stone Moorestown, NJ (609)-234-7263	2/3/89	36	Clay	Low Permeability Material	

NOTES:
1. ** indicates that potential supplier provided results of laboratory analyses performed for samples obtained from source indicated. However, these analyses were not performed as part of this investigation.

testing was performed by Empire Soils Investigations, Inc. located in Groton, New York. In addition, several potential suppliers provided results of laboratory analyses previously performed on samples collected from sources indicated in Table 2-11. These analyses were not performed specifically as part of this investigation. Samples taken from sources where laboratory analyses had been performed previously were not selected for laboratory analyses in order to avoid duplication of information and maximize the amount of laboratory test data available. Appendix 2-9 presents the results of the laboratory analyses.

Granular Materials

As discussed in the FSTP, it was intended to sample granular materials to evaluate their suitability in the construction of roads and components of the cap system, including a gas venting layer if required. Two types of granular materials were collected; including crushed stone and sand. It was anticipated that the crushed stone be used in the construction of roads and, if required, the gas venting layer component of the cap system. It is noted that the final cap design incorporates an active gas venting system, and a passive gas venting layer in the cap system is not included, as previously discussed. Similarly, it is anticipated that the sand materials may be utilized to construct the drainage layer component of the cap. Based on results of the HELP model analyses, it appears that sand materials may meet the minimum hydraulic conductivity requirements for use as the drainage layer.

It is anticipated that materials utilized for construction of the roads will be in accordance with the New Jersey Department of Transportation (NJDOT) specifications. Mechanical grain size analyses for the samples collected were evaluated to determine their suitability for use in road construction with respect to NJDOT specifications. Based on results of the laboratory tests, it appears that the materials sampled do not meet NJDOT specifications for material type I-5. The materials sampled are uniformly graded and would likely require the addition of fine materials to create a well graded material. Generally, well graded materials are more likely to achieve higher levels of compaction. The materials could be made suitable through the addition of fine grained materials. It is likely that alternate local sources of bank run materials may meet NJDOT specifications.

Table 2-12 summarizes the estimated hydraulic conductivities for the granular materials analyzed based on the Hazen approximation which is:

$$K = 100D_{10}^{2}$$

where k = hydraulic conductivity (cm/sec)

D_{10} = diameter of particle where 10 percent of the material passes by weight (cm)

Materials proposed for use in construction of the drainage layer and gas venting layer should have a minimum hydraulic conductivity of 1×10^{-2} cm/sec. The gas venting layer is not recommended as part of the final design. In addition, no more than 5 percent of the material should pass the number 200 sieve.

TABLE 2-12
COMBE FILL SOUTH LANDFILL MATERIALS INVESTIGATION
SUMMARY OF LABORATORY ANALYSES FOR GRANULAR MATERIALS

SAMPLE	D10 (cm)	k=100D102 (cm/sec)	PERCENT PASSING NUMBER 200 SIEVE	SOURCE OF LABORATORY ANALYSES (1)	QUANTITY AVAILABLE (2) (cubic yards)
Berkshire - 28 Concrete Sand	N/A	N/A	N/A	N/A	40,000
Dallenbach -4 Concrete Sand	0.027	7.3x10-2	0.9	Supplier	58,000 (4)
Dallenbach -5 Masonry Sand	0.02	4.0x10-2	0.9	Supplier	58,000 (4)
Mount Hope - 24 Washed Stone Sand	0.021	4.4x10-2	1.9	Supplier	116,000
Piocosta - 17 Concrete Sand	N/A	N/A	N/A	N/A	58,000
Piocosta - 18 Screened Bank Run Sand	0.01	1x10-2	8	Empire Soils	58,000
Raia Industries - 34 Concrete Sand	0.02	4.0x10-2	3.5	Supplier	116,000
Raia Industries - 32 -3/8 Sand Fill	0.01	1.0x10-2	4.8	Supplier	116,000
Saxton Falls - 21 Sandy Bank Run	N/A	N/A	N/A	N/A	66,000
Urbano - 9 Sand	0.0074 (5)	5.5x10-3	11.5	Empire Soils	116,000
Berkshire - 29 3/4 inch rounded gravel	N/A	N/A	N/A	N/A	50,000
Berkshire - 30 3/4 inch crushed stone	N/A	N/A	N/A	N/A	50,000
McNear Excavating - 8 3/4 inch crushed stone	N/A	N/A	N/A	N/A	123,000
Millington - 3 3/4 inch crushed stone	0.11	1.21	0	Empire Soils	123,000
Mount Hope - 24 3/4 inch crushed stone	0.8	64	0	Supplier	123,000
Piocosta - 19 1.5 inch crushed stone	N/A	N/A	N/A	N/A	50,000
Raia Industries - 33 3/4 inch crushed stone	0.8	64	0	Supplier	123,000
Saxton Falls - 20 3/4 inch crushed stone	N/A	N/A	N/A	N/A	26,000
Tri-County - 26 3/4 inch crushed stone	0.12	1.4	0	Empire Soils	123,000
Tri-County - 27 1.5 inch crushed stone	N/A	N/A	N/A	N/A	123,000
Urbano - 10 1.5 inch crushed stone	0.19	3.6	2	Empire Soils	123,000

NOTES:
(1) Indicates that potential supplier provided results of laboratory analyses performed for samples obtained from source indicated. However, these analyses were not performed as part of this investigation.
(2) Indicates estimated quantity available for 1989-1990.
(3) Indicates costs are based on November, 1988 costs for material deliverd to site.
(4) Indicates supplier indicated that total quantity available may be 116,000 Cubic yards, based on use of both types of sands.
(5) Indicates D10 estimated on percent passing the number 200 sieve, where 11.5 percent pass the number 200 sieve.

Based on the information presented in Table 2-12, it appears that sand materials collected from Dallenbach Sand, Mount Hope Rock Products, and Raia Industries meet requirements for use in construction of the drainage layer. These samples have hydraulic conductivities ranging from 1.0 x 10^{-2} to 7.3 x 10^{-2} cm/sec based on Hazen's approximation. The Urbano-9 and Piocosta-18 samples had greater than 5 percent of the material passing the number 200 sieve, which make them unsuitable for use in the drainage layer without additional sieving.

Table 2-12 indicates that for the crushed stone samples analyzed, the hydraulic conductivities ranged from 1.2 to 64 cm/sec based on Hazen's approximation. Samples obtained from Millington, Mount Hope, Raia Industries, Tri-County, and Urbano appear to meet requirements for hydraulic conductivities greater that 1 x 10^{-2} cm/sec.

Low Permeability Materials

A total of eight potential sources of low permeability material were identified. The cap will likely incorporate a low permeability soil barrier. Table 2-13 summarizes the results of the laboratory analyses for the low permeability samples. Results of laboratory analyses for materials obtained from Dallenbach Sand and McNear Excavating were provided by the potential suppliers. These analyses were not performed specifically as part of this investigation. Five additional samples were selected for laboratory testing in accordance with the FSTP and included samples from Berkshire Sand and Gravel, County Sand and Stone, Piocosta, Saxton Falls Sand and Gravel, and

TABLE 2-13

COMBE FILL SOUTH LANDFILL MATERIALS INVESTIGATION
SUMMARY OF LABORATORY ANALYSES FOR LOW PERMEABILITY SOILS

SAMPLE	USCS CLASSIFICATION	MOISTURE DENSITY (2) (LB/FT3)	PERCENT MOISTURE (2)	HYDRAULIC CONDUCTIVITY (2) (CM/SEC)	LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	SHEAR STRENGTH (LB/IN2)	SOURCE OF LABORATORY ANALYSES (1)	QUANTITY AVAILABLE (4) (cubic yards)	COST (5) (per CY)	APPROXIMATE DISTANCE FRO SITE (miles
Berkshire - 31	SM	113.2	15.1	1.37x10-5 1.50x10-5	21	20	1	31.2	Empire Soils	30,000	$18.00	25
County Sand & Stone - 36	CH	89.0	27.4	1.94x10-6 2.28x10-6	87	28	59	26.1	Empire Soils	233,000	$20.00	80
Dallenbach - 2	CH - sample 1 CL - sample 2	114.1 - sample 1 (3) 114.8 - sample 2 (3)	N/A N/A	2.28x10-7:sample 1 (3) 2.0x10-9:sample 2 (3)	54 N/A	38 N/A	16 N/A	N/A N/A	Supplier Supplier	233,000 (6)	$18.00	35
McNear - 6	SM - sample 1 SM - sample 2	135.8 - sample 1 (3) 133.6 - sample 2 (3)	6.8 - sample 1 8.0 - sample 2	1.02x10-4:sample 1 (3) 1.63x10-4:sample 2 (3)	NP NP	NP NP	NP NP	NP NP	Supplier Supplier	233,000	$10.00	15
Mount Hope - 35	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	233,000	$10.00	70
Piocosta - 16	SM	130.6	9.4	4.9x10-5 4.6x10-5	NP	22	NP	27.1	Empire Soils	233,000	$20.00	15
Saxton - 22	ML	108.3	17.3	9.5x10-6 9.7x10-6	23	20	3	24.2	Empire Soils	33,000	$8.00	10
Urbano - 11 (6)	CL	90.6	25.5	1.2x10-7 1.4x10-7	44	24	20	28.9	Empire Soils	233,000	$22.00	40

NOTES:
(1) Indicates that potential supplier provided results of laboratory analyses performed for samples obtained from source indicated. However, these analyses were not performed as part of this investigation.
(2) Indicates that moisture density relationships and corresponding permeability tests were performed with the 15 blow modification to ASTM D-698 unless otherwise noted.
(3) Indicates that these tests were performed in accordance with ASTM D-1557 Method C, Modified Proctor methods.
(4) Indicates estimated quantity available for 1989-1990.
(5) Indicates costs are based on November, 1988 costs for material delivered to site.
(6) Indicates quantity available is based on efficiency of wet mining process used to obtain the material.
(7) NP indicates Non-Plastic.
(8) N/A indicates not ascertained.
(9) See note from Empire Soils regarding behavior of soil observed during laboratory analyses in Attachment 1.

Urbano. The Mount Hope and County Sand and Stone samples were collected at a later date than the other samples. Prior to that time, a total of four of the five low permeability samples had been selected for laboratory testing. Based on visual inspection of the samples and available cost information, the County sample was submitted as the fifth sample for testing.

Soil samples were analyzed for the following parameters:

Parameter	Standard
Mechanical and Hydrometric Grain Size	ASTM D422-64
Moisture Density Relationship	ASTM D698-78 with 15-blow modification
Remolded Permeability with Back Pressure Saturation	U.S. Army Corps of Engineers Manual EM110-2-1906 Appendix VII
Parameter	Standard
Atterberg Liquid and Plastic Limits	ASTM D4318-73
Unconsolidated, Undrained (UU) Triaxial Shear Strength of Compacted Samples	ASTM D2850-82

The 15-blow modification to ASTM D698-78 (Standard Proctor Compaction) was used for testing of proposed low permeability materials to model compaction of cover material on municipal solid waste as recommended in the EPA Document 600/2-79-165 "Design and Construction of Covers for Solid Waste Landfills". It is likely that greater compaction could be achieved at the site due to age of the waste and existing cover. Therefore, potential exists to achieve hydraulic conductivities less than those measured with the 15-blow modification. The Standard Proctor Compaction Test requires compaction of a sample in three equal layers in a standard mold. Each layer receives 25 blows from a 5.5 pound hammer falling 12 inches. The 15-blow modification to this procedure provides each layer with only 15 blows, which represents a lesser compactive effort.

Results of the laboratory analyses provided for the Dallenbach and McNear samples indicate that tests were performed in accordance with ASTM D-1557 (Modified Proctor Compaction). The Modified Proctor Compaction Test requires compaction of a sample in five equal layers in a standard mold. Each layer receives 25 blows from a 10 pound hammer falling 18 inches. The Modified Proctor Compaction Test models a greater level of compactive effort. Therefore, the hydraulic conductivities measured with samples prepared in accordance with Modified Proctor Compaction test methods may represent the lower range of hydraulic conductivities for the soil.

Samples obtained from Berkshire, McNear, and Piocosta are classified as silty sands (SM) according to the USCS. Hydraulic conductivities for these samples ranged from approximately 1.4×10^{-5} to 1.6×10^{-4} cm/sec and are greater than the maximum required permeability of 1×10^{-7} cm/sec for the soil barrier layers. In addition, the McNear and Piocosta samples are classified as non-plastic. The Berkshire sample has a plasticity index of 1. Based on the results of the laboratory analyses, it appears that these soils are not suitable for use in construction of the soil barrier layer. However, it is possible that they could be made suitable by the addition of bentonite.

The sample obtained from Saxton Falls is classified as a low plasticity silt (ML). This material is a product of a crushed stone washing process at the quarry and only a limited amount of the material, approximately 33,000 cubic yards, is likely to be available. Laboratory results indicate that the hydraulic conductivity for the material is approximately 9.7 x 10-6 cm/sec, exceeding the minimum requirement for use in construction of the soil barrier layer. The addition of bentonite could potentially allow the material to meet hydraulic conductivity requirements.

The sample obtained from County Sand and Stone is classified as a highly plastic clay (CH). Hydraulic conductivities for the sample were in the range of 1.94 x 10^{-6} to 2.28 x 10^{-6} cm/sec. The material has a plasticity index of 59. Based on information presented by Seed et al. (1962) in An Introduction to Geotechnical Engineering by R.D. Holtz and W.D. Kovacs, the clay may have the potential to swell. The potential to swell can be assessed through expansion or swell laboratory tests if this is deemed necessary.

The sample obtained from Urbano is classified as a low plasticity clay (CL). The hydraulic conductivities for the sample ranged from 1.2 x 10^{-7} to 1.4 x10^{-7} cm/sec. It is important to note the observations made during laboratory analyses of the sample by the soils laboratory. A description of the behavior of the sample is included in Appendix 2-9. Prior to testing, the sample was dried in an oven. After this initial drying, the sample had the appearance of cinders. Material retained on the number 4 sieve was washed with tap water, and the material immediately dissolved, leaving approximately 0.4 pounds of orange gravel which stained the technician's skin orange. According to the laboratory report, the sample had an unusual but unidentifiable odor. Oven dried samples taken after the permeability test had been completed indicated that the sample again had the appearance of cinders. The samples were uneven in color, with some areas having the appearance of still being wet or possibly containing a foreign substance. Although the hydraulic conductivities are near those required for construction of the soil barrier layers, the behavior of the soil indicates that it may not be suitable for use in construction of the cap system.

Laboratory analyses for the soils present at the Dallenbach site indicate the soil is classified as a low to high plasticity clay (CL/CH) according to the USCS. Hydraulic conductivities for the samples ranged from 2.0x10-9 to 2.3x10-7 cm/sec. It is noted that the laboratory tests were performed with samples that had been prepared to 95 percent compaction as per the Modified Proctor Compaction test. As previously indicated, the hydraulic conductivities measured with samples prepared in accordance with Modified Proctor Compaction test methods may represent the lower range of hydraulic conductivities for the soil. It appears that clay soils obtained from this site have the potential to meet the requirements for the soil barrier layers. However, the material is obtained as a result of a wet mining process used to obtain sand material from adjacent soil layers. Consequently, the quantity of material available may be dependent on the efficiency of the mining operation and time required to dry the material following mining. In order to assess the hydraulic conductivity of the soil with the 15-blow modification to the Standard Proctor Compaction test, additional testing will need to be performed.

Topsoil

A total of four potential sources of topsoil were identified. Table 2-14 presents the results of laboratory tests performed on three of the potential topsoil sources. The source from which the Urbano topsoil sample was obtained is likely to change. In that case, additional analyses would be required to evaluate the suitability of the

TABLE 2-14
COMBE FILL SOUTH LANDFILL MATERIALS INVESTIGATION
SUMMARY OF LABORATORY ANALYSES FOR TOPSOIL

	SAMPLE COMO-1	SAMPLE PIOCOSTA-14	SAMPLE URBANO-13 (5)
PERCENT PASSING NUMBER 200 SIEVE	24.2	33.3	60.0
MOISTURE DENSITY (1) (LB/FT3)	114.6	117.4	105.7
PERCENT MOISTURE (1)	15.1	12.8	19.2
Phosphorous, available (mg/Kg)	2.4	2.5	2.2
Potassium, available (mg/Kg)	27	37	49
Magnesium, available (mg/Kg)	109.7	398.1	148.9
Calcium, available (mg/Kg)	754	1383	722
Iron, available (mg/Kg)	7.5	1.2	29.7
Aluminum, available (mg/Kg)	25.3	16.7	67.6
Manganese, available (mg/Kg)	8.2	11.7	85.7
Zinc, available (mg/Kg)	0.68	0.37	0.90
Copper, available (mg/Kg)	-0.3 (4)	-0.4 (4)	0.4
pH, in water	6.87	7.49	5.12
Organic Matter LOI percent	2.50	3.54	5.95
NO3, available (mg/Kg)	6.85	25.14	32.03
NH3, available (mg/Kg)	4.4	1.2	4.0
CEC-NH4OAc cmol/Kg	6.61	9.09	17.55
Exchange Acidity (cmol/Kg)	N/A	N/A	8.37
QUANTITY AVAILABLE (2) (cubic yards)	59,000	59,000	59,000
COST per cubic yard (3)	$25.00	$26.00	$20.00
APPROXIMATE DISTANCE FROM SITE (miles)	30	15	20

NOTES:
(1) Indicates that moisture density relationships were performed with the 15-blow modification to ASTM D-698 (Standard Proctor Compaction).
(2) Indicates estimated quantity available for 1989-1990.
(3) Indicates costs are based on November, 1988 costs for material delivered to site.
(4) A minus sign indicates analyte at limit of detection, it does not indicate a negative result.
(5) Indicates source of material likely to change.
(6) N/A indicates Not Ascertained.

topsoil from the new source if that source was selected for use in the cap system. A topsoil sample to be sent by Berkshire Sand and Gravel did not arrive and was not included in the laboratory testing program. In addition, the other suppliers had indicated that the entire quantities required could be supplied and were, therefore, considered to be preferable sources.

The topsoil will promote growth of a vegetative layer which will stabilize the cap, promote run-off, maximize evapotranspiration, minimize infiltration, and minimize soil erosion. In addition, the topsoil should be capable of supporting a vegetative species which is adapted to the climate of the region, relatively quick growing, shallow rooted, able to grow year round, self propogating, and require a minimum of short and long-term maintenance.

The samples were analyzed for the parameters listed in Table 2-14. In order to evaluate the suitability of these soils for support of the vegetative species on the landfill cap system, the Morris County Soil Conservation Service was contacted. A copy of the correspondence from the Soil Conservation Service is included in Appendix 2-9. Results for the third topsoil sample from Urbano were not available at the time the other test results were forwarded to the Soil Conservation Service. According to the Soil Conservation Service, the levels of the macronutrients nitrogen (N), phosphorous (P), and Potassium (K) and micronutrients are unusually low for the Como and Piocosta samples. In addition, the pH levels are 1 or 2 units higher than is typical for the upland soils in Morris County. The organic matter levels are within the normal range for the A horizon of most of the well-drained soils in Morris County. The cation exchange capacity (CEC) levels were low for the Como and

Piocosta samples. Based on recommendations by the Soil Conservation Service, it appears that the materials are suitable as a growth medium for sod.

Levels of the parameters evaluated for the Urbano sample were generally within the ranges of those measured for the Como and Piocosta samples with the exception of potassium (K), iron (Fe), aluminum (Al), manganese (Mn), organic matter, nitrate (NO3), and cation exchange capacity, which were detected at higher levels. The pH level for the Urbano sample was 5.12, slightly lower than the levels measured for the Como and Piocosta samples.

Synthetic Materials

As part of the materials evaluation program, a review of synthetic materials to be used in the construction of the cap system was performed. The materials evaluated include geomembranes, geotextile, and geosynthetic materials likely to be utilized as the surface water collection removal systems (SWCR). A discussion of geomembrane of materials evaluated for use as the Flexible Membrane Cover (FMC) is presented in Section 2.03.03. Based on frictional, stress-strain characteristics, and low temperature brittleness values, the use of LDPE material as the FMC is recommended.

Geotextile materials proposed for use in the cap system as geosynthetic filters were evaluated. Generally, these materials consist of nonwoven polypropylene. Typical properties of geotextile materials designed for separation, reinforcement, drainage, and filtration were used to determine if the material would meet requirements for permittivity and filtration for use in the cap systems based on results of the HELP model runs. It is likely that several geotextile fabrics are capable of meeting the appropriate filter criteria. In addition, it appears that the materials have sufficient strain at rupture to avoid failure due to settlement for the conditions modeled. It is recommended that the geotextile material have a minimum unit weight of 12 oz/yd2 Correspondence with technical representatives of geotextile manufacturers indicates that heavier geotextiles are more likely to withstand construction activities in satisfactory condition than lighter weight materials.

Two types of materials were evaluated for use in the cap system as the surface water collection/removal system (SWCR). These materials include geonet material manufactured of HDPE and a geocomposite material manufactured from HDPE with geotextile materials heat sealed over both sides of the geonet. The properties of Gundnet XL-4 were used to evaluate the geonet. Properties corresponding to Tenax TNT material were used to evaluate the geocomposite material. As previously discussed, this is not meant to specify these materials in particular. The properties were used as a basis for determining the general material properties of such materials. Based on analyses performed and available information, it appears that the geonet material manufactured by Gundle or a material with similar characteristics will provide sufficient transmissivity for use as the SWCR layer. It is noted that information regarding the tensile strength of the geonet material was requested from the manufacturer to evaluate the likelihood of failure due to shear of the geonet and if the material has sufficient strain at rupture to avoid failure due to settlement. However, this information does not appear to be readily available.

Based on available information, it is likely that the geocomposite material Tenax material or a material with similar characteristics would have tensile properties sufficient to avoid failure due to shear or due to settlement. However, analyses based on available information indicate that the material may not provide sufficient transmissivity.

Gabions

Gabion walls used as retaining structures to stabilize the cap system near the edge of waste decrease additional quantities of materials required for cap construction beyond the limit of waste deposits. Manufacturer's literature provided by Maccaferri Gabions was reviewed, although, this is not meant to specify Maccaferri gabions in particular. Maccaferri heavy duty gabions are rectangular baskets made of zinc-coated steel wire mesh of double twist hexagonal weave having openings of 3.25 by 4.50 inches. Each gabion is subdivided into cells of equal size by diaphragms.

At the construction site, the gabions are unfolded and assembled by lacing the edges together and fixing the diaphragms to the sides. The individual gabion units are then laced to each other and filled with stone larger than the openings in the mesh, generally ranging from 4 to 8 inches in diameter. The lids are then closed and laced to the top edge of the individual gabions.

Maccaferri also manufactures gabions with a PVC coated mesh. Due to their greater resistance to corrosion, it is recommended that these gabions be used at the landfill as the manufacturer indicates that these gabions be utilized in cases where the soil or water is acidic, in salt or brackish water, or wherever the risk of corrosion is present.

Table 2-15 summarizes potential suppliers for material which may be used to fill the gabions. It is noted that no samples were collected from these potential suppliers. Manufacturer's literature from Maccaferri Gabions indicates that materials used to fill the gabions should meet the structural, functional, and durability requirements of the project. The selected stone must be weather resistant, non-firable, insoluble, and sufficiently hard to ensure the durability of the structure. Based on information presented in Table 2-15, it appears that there are several sources which are capable of supplying the estimated quantities of stone suitable for use in gabion construction.

Summary

Results of the materials investigation indicate that sufficient quantities of materials likely to be used in the construction of the topsoil, vegetative, and drainage layers and gabion walls appear to be available within a 35-mile radius of the site. Samples collected for use as low permeability material to be used in the construction of the soil barrier layer were tested in the laboratory with the 15-blow modification to the Standard Proctor Compaction test in order to model the compaction of cover material on municipal waste. Based on the results of these tests, several of the samples do not appear to be suitable for use in the construction of the soil barrier layer with respect to the measured hydraulic conductivities. However, it is possible that these materials could be made suitable through the addition of bentonite. In addition, it is likely that greater levels of compaction could be achieved at the site due to age of the waste and the presence of an existing cover.

Laboratory analyses for soils available from the Dallenbach Sand and Stone site indicate that the hydraulic conductivity ranges from 2.0×10^{-9} to 2.3×10^{-7} cm/sec. It appears that these soils have the potential to meet the requirements for use in the construction of the soil barrier layers. However, the quantity of material available

TABLE 2-15

COMBE FILL SOUTH MATERIALS INVESTIGATION

SUMMARY OF POTENTIAL SOURCES FOR GABION FILL MATERIAL

SAMPLE	QUANTITY AVAILABLE (1) (cubic yards)	COST (per cubic yard) (2)	APPROXIMATE DISTANCE FROM SITE (miles)
McNear Excavating	22,000	$15.00	15
Millington Quarry	22,000	$21.00	15
Piocosta Sand and Gravel	22,000	$22.00	15
Raia Industries	22,000	$26.00	30
Saxton Falls Sand and Gravel	22,000	$20.00	10
Tri-County Asphalt	22,000	$17.00	20
Urbano	22,000	$22.00	25

NOTES:

(1) Indicates estimated quantity available for 1989-1990.

(2) Indicates costs are based on November, 1988 costs for material delivered to site.

may be dependent on the efficiency of the wet mine operation used to obtain the soil. In general, it appears that sufficient quantities of material with the potential to meet requirements for the soil barrier layer through the addition of bentonite are available within a 35-mile radius of the site.

Geosynthetic materials proposed for use in the construction of the cap system were also evaluated. In general, it appears that a LDPE material is acceptable for use as the FMC component of the cap system. LDPE material appears to be more advantageous in cases where the FMC is likely to be subjected to significant settlements because of their more favorable stress-strain characteristics. In cases where chemical compatibility is of a concern, the use of HDPE materials may be more favorable because of their resistance to a wider range of chemicals. Recognizing that a 2 foot thick soil barrier layer will likely separate the waste layer from the FMC in the selected cap design and that settlement of the cap system is a concern, a FMC manufactured of LDPE is most appropriate.

Geotextile materials manufactured of nonwoven polypropylene or polyester appear to meet requirements for permittivity and filtration in the cap system. Several geotextile fabrics are capable of meeting the appropriate filter criteria.

Geosynthetic materials evaluated for use in the cap system as the surface water collection/removal system (SWCR) include a geonet material manufactured of HDPE and a geocomposite material consisting of a geonet manufactured of HDPE with geotextile materials heat sealed over both sides of the geonet. Based on the analyses performed and available information, it appears that the geonet has the ability to provide sufficient transmissivity for the SWCR layer. However, information regarding the tensile strength of the material was not available and the likelihood of failure due to shear of the geonet could not be evaluated. The geocomposite material did not appear to provide sufficient transmissivity for the SWCR layer.

2.04 Grading Plan

2.04.01 Final Grade

The proposed final grades are shown on Sheet 2 of the Design Drawings. During placement of the final cover, top slopes will be graded to a minimum of four percent and side slopes to a maximum of vertical on 4.5 horizontal to ensure proper drainage, control erosion, and minimize infiltration as discussed in the Promotion of Drainage and Minimization of Erosion or Abrasion Section of Section 2.03.05. A maximum slope of 1 vertical on 4.5 horizontal was selected based on results of stability analyses of the cap components. It is noted that maximum slopes of 1 vertical of three horizontal are acceptable according to the New Jersey Administrative Code (NJAC) 7:26-2A.8(b)(5).

2.04.02 Gabion Walls

In order to minimize the amount of refuse to be relocated and the amount of embankment material required to achieve final grades, and meet grading criteria imposed by the presence of wetlands and a right of way, it was determined that the construction of a retaining or gabion wall was required at the limits of the capped areas. Construction of a retaining or gabion wall will prevent the side slope of additional embankment material from extending into the wetland areas and the New Jersey Power and Light right-of-way.

A series of analyses were performed to develop preliminary retaining and gabion wall designs. In addition, cost estimates were prepared for construction of gravity retaining, cantilever retaining, and gabion walls on a per foot basis. Based on available information during the initial stages of the preliminary design, it was estimated that a wall with a maximum height of nine feet was required. The costs estimates were based on literature from Maccaferri Gabions and 1989 Means Site Work Cost Data and are as follows:

Type of Wall	Wall Height	Estimated Cost of Construction per Construction Foot
Gravity Retaining	9 ft.	$210.00
Cantilever Retaining	9 ft.	$235.00
Gabion	9 ft.	$ 85.00
Gabion	6 ft.	$ 60.00

The cost estimates indicate that a nine foot high gabion wall costs approximately 35 percent of the cost to construct a gravity or cantilever retaining wall. Therefore, it appears that the gabion wall is most cost-effective. Modifications to the preliminary grading plan showed that a six foot high gabion wall would be sufficient. The cost of construction on a per foot basis for a six foot high gabion retaining wall is estimated to be $60.00. Given the relatively large difference in construction cost between the gabion and gravity or cantilever retaining walls for the nine foot high walls, it is anticipated that the gabion walls are the most cost-efficient for a wall height of six feet.

The gabions will consist of PVC coated steel wire mesh cages filled with stone four to eight inches in diameter.

2.05 Subsurface Water Controls

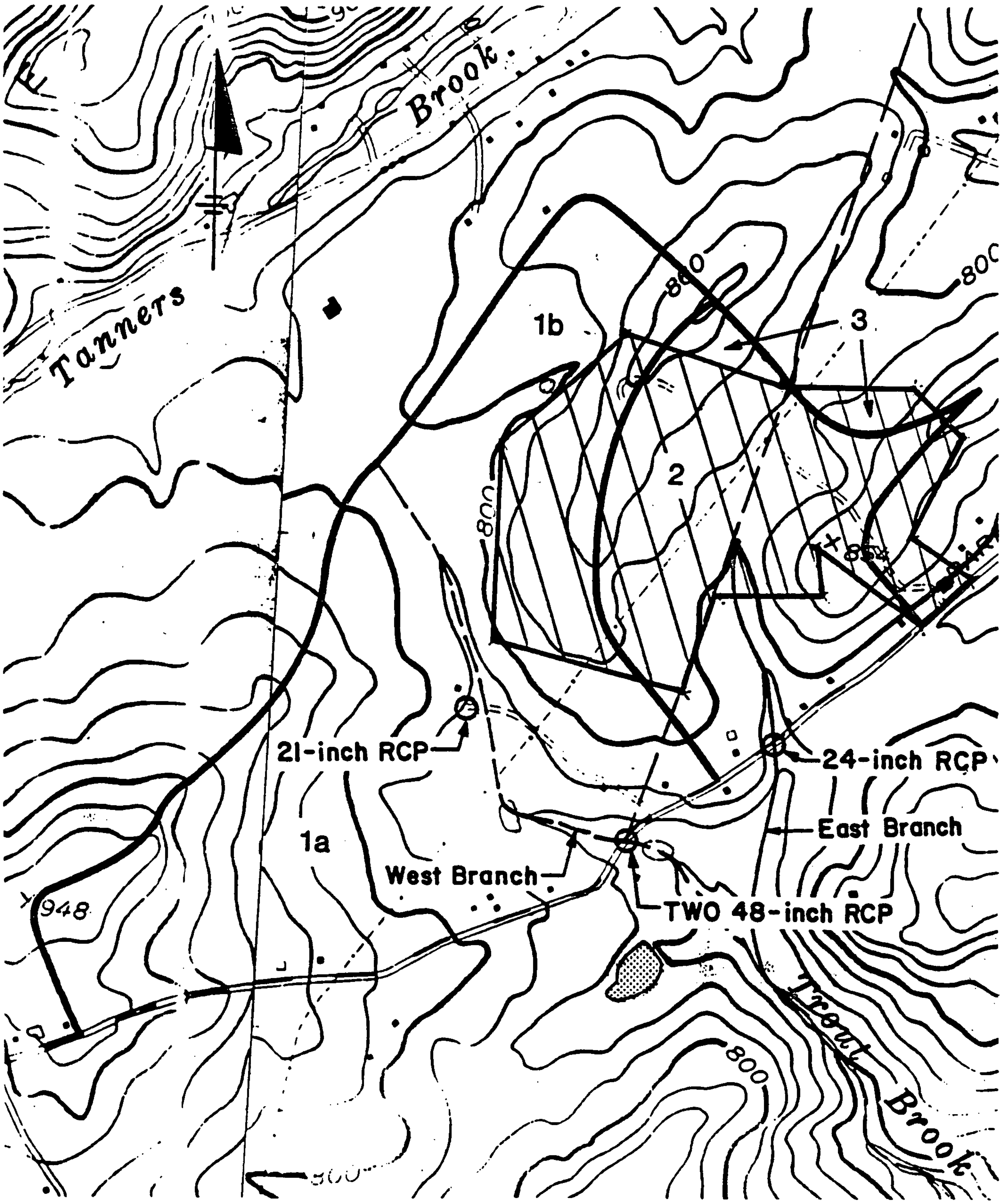
A system of drainage pipes will be installed in the drainage layer to promote more rapid flow of water within the layer. The pipe drainage system consists of four inch diameter perforated and solid poly-vinyl chloride pipe (PVC) and directs flow toward the perimeter drainage ditch. Analyses performed for the subsurface drainage system are presented in Appendix 2-10. The lateral spacing of the pipe was determined in accordance with recommendations presented in the Soils Mechanics Design Manual 7.1 prepared by the Department of the Navy. Based on the conditions modeled, a maximum lateral spacing of 170 feet was determined for areas with minimum slopes of four (4) percent. Laterals placed at this spacing will promote more rapid dissipation of water in the layer. In addition, the laterals will improve the stability of the more steeply graded slopes by minimizing the length of the drainage path.

2.06 Surface Water Controls

2.06.01 Existing Drainage Conditions

The Combe Fill South Landfill site is located within the drainage basin of Trout Brook at the head waters of west and east branches of Trout Brook as shown on Figure 2-9. Trout Brook flows southeast toward the Black River. Tanners Brook flows northeast of the landfill to its junction with the Black River. The Black River flows to the south where it joins Trout Brook approximately 1.5 miles southeast of the landfill and flows south to the Raritan River. The site is situated on a local topographic high and surface waters drain

Figure 2-9



COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
SITE DRAINAGE FOR SURFACE RUNOFF ANALYSES

NOTE: RCP INDICATES REINFORCED CONCRETE PIPE

SCALE: 1" = 1000 ft.

radially from the site. The total drainage area occupies approximately 351 acres divided into three separate sub-areas; 1, 2, and 3, as shown on Figure 2-9.

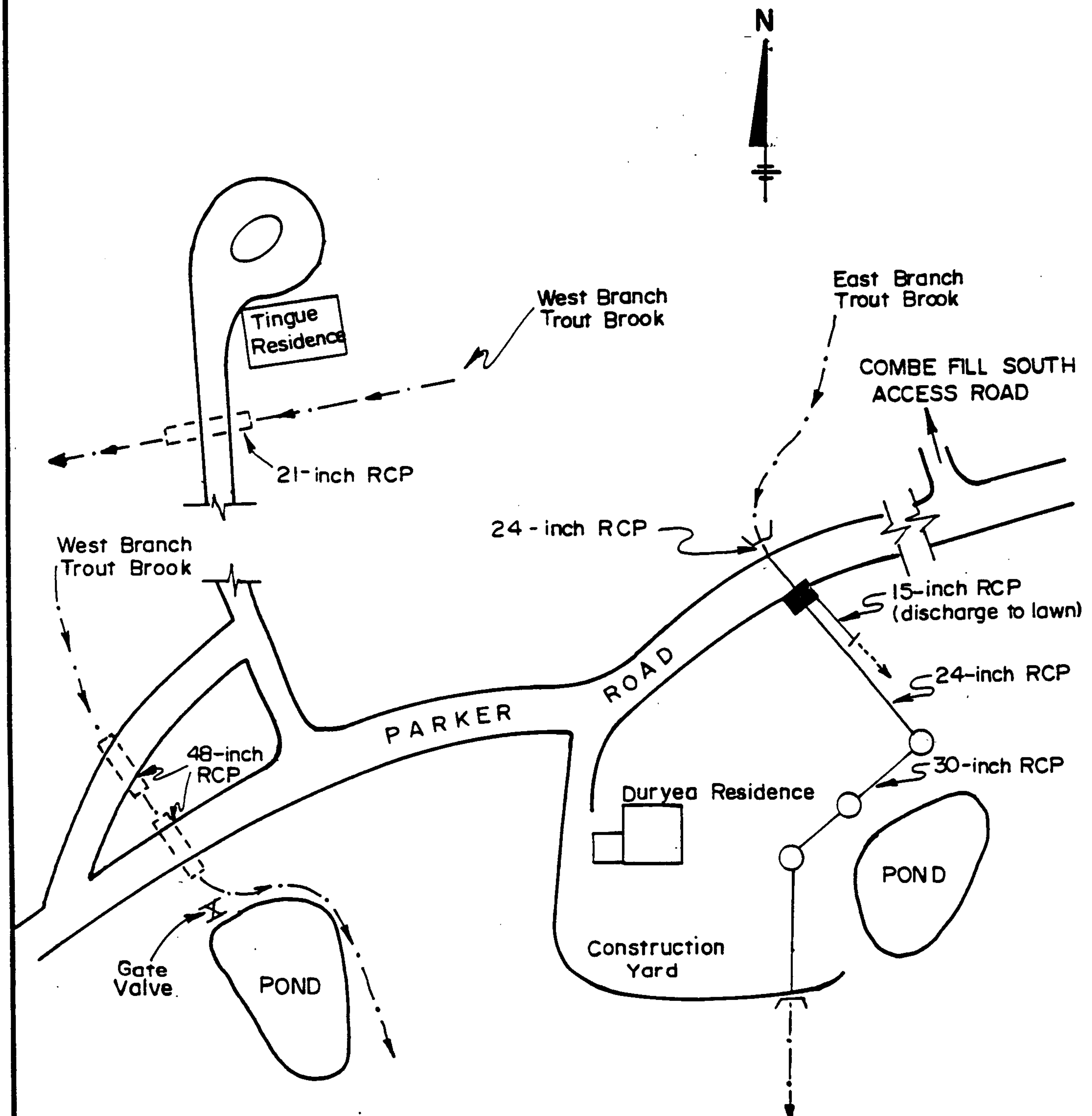
Subarea 1 is comprised of approximately 247 acres of which 235 acres are woods covered. The remaining 12 acres are primarily brush and grass covered. This area drains southwest to the West Branch of Trout Brook discharging under Parker Road via an existing 48-inch reinforced concrete culvert. There are two additional culverts within this drainage system including a second 48-inch reinforced concrete pipe immediately upstream of Parker Road and a 21-inch reinforced concrete pipe approximately 1500 lineal feet upstream of the Parker Road crossing as shown on Figure 2-10.

Subarea 2 is comprised of approximately 97 acres, of which 47 acres are forested. The remaining 50 acres are primarily brush and grass covered. This area drains to the East Branch of Trout Brook discharging under Parker Road via an existing 24-inch reinforced concrete pipe culvert and storm system.

Subarea 3 includes a small section of the northeast corner of the landfill. Approximately 7-acres drain to the northeast toward a small unnamed tributary of the Black River. The ground cover consists of a mixture of brush and grass.

2.06.02 Cap System Surface Water Controls

Surface runoff from the capped areas of the landfill will be directed to the site perimeter drainage ditch. Surface water diversion ditches will be installed on the cap to minimize erosion. Potential erosion losses were estimated using information regarding the Universal Soil Loss Equation as presented in the Standards for Erosion and Sediment Control in New Jersey.



Note: RCP indicates reinforced concrete pipe

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

CULVERT LOCATIONS

NOT TO SCALE

063397

Based on the conditions modeled, it was determined that erosion loss would be small following the establishment of a grass cover. However, guidelines presented in the EPA document Covers for Uncontrolled Hazardous Waste Sites recommend that diversions should be provided whenever the vertical interval (height) of any one (1) vertical on two (2) horizontal through one (1) vertical on five (5) horizontal slopes exceeds 15 feet. Therefore, surface water diversion ditches will be installed at 15 foot changes in elevation. Cap drainage ditches lined with rip rap will convey surface flows to the perimeter drainage ditch. In areas where gabion walls are constructed on the site, perimeter surface runoff will flow downward through the gabion walls towards the perimeter drainage ditch. Rip-rap channels will direct surface flows along the more steeply graded portions of the landfill cap towards the perimeter drainage ditch.

2.06.03 Storm Runoff Flow Analysis

A storm runoff flow analysis was performed utilizing the TR-55 program "Urban Hydrology for Small Watersheds" developed by the Soil Conservation Service. A 25-year 24-hour storm frequency yielding 5.8 inches was used to evaluate the flow capacities of the existing systems. This storm was determined based on requirements for Design of Sanitary Landfills presented in N.J.A.C. 7:26-2A(f)(3). Runoff calculations were computed to estimate storm flows prior to and after site remediation.

TABLE 2 - 16

Combe Fill South Landfill
Morristown County, New Jersey

RESULTS OF STORM RUNOFF FLOW ANALYSIS (1)

Drainage Area	Number of Acres	Pre-Construction Peak Flows (Cubic Feet per Second) (2)	Post-Construction Peak Flows (Cubic Feet per Second
1	135	136 cfs (13.2 hours)	137 cfs (13.2 hours)
1	112		
2	97	54 cfs (12.6 hours)	63 cfs (12.6 hours)
3	7.5	6 cfs (12.6 hours)	8 cfs (12.6 hours)

Notes:

(1) Peak flows based on results from TR-55 program "Urban Hydrology for Small Watersheds" developed by the Soil Conservation Service.

(2) Indicates the corresponding time to peak flow during a 25-year 24-hour storm.

TABLE 2-17

Combe Fill South Landfill
Morris County, New Jersey

ESTIMATED CAPACITIES OF EXISTING CULVERTS

Drainage Area	Pipe Dia.	Pipe Material	Length	Slope	Distance from Invert to Centerline of Road	Headwater/Diameter (HW/D) (Type 3 Entrance Type)	Flow Capacity (Inlet Control)
I	21-inch	RCP	28'	.0175	2.75'	1.6 ft.	17 cfs.*
I	48-inch	RCP	29'	.0231	5.0'	1.25 ft.	105 cfs.*
I	4-inch @ Parker Rd.	RCP	50'	.006	7.4'	1.85 ft.	152 cfs.*
II	24-inch @ Parker Rd.	RCP	42'	.018	8.0'	4.0 ft.	45 cfs.*
II	24-inch	RCP	128'	.029			35 cfs.**
II	15-inch	RCP	38'	.034			10 cfs.**
II	30-inch	RCP	174'	.029			60 cfs.**

otes:

1) RCP indicates reinforced concrete pipe.

2) * Q discharge determined from Chart No. 2 of the "Hydraulic Charts for the Selection of Highway Culverts" for inlet control developed by U.S. Department of Transportation - Federal Highway Administration.

3) ** Flow capacities determined from flow charts developed by U.S. Department of Commerce, Bureau of Public Roads - "Design Charts for Open-Channel Flow". Flow based on full pipe flow at respective slopes using a roughness n = 0.012.

2.06.04 Results of Storm Runoff Flow Analysis

Results of the storm runoff analysis are presented in Table 2-16. Detailed results of the computer analyses are included in Appendix 2-11. Table 2-17 summarizes data collected to determine capacities of the existing culverts. Based on downstream conditions, it is anticipated that pipe capacity will be determined by the inlet control.

Subarea 1 Surface Water Runoff Control

As previously discussed, there are three culverts within the Subarea 1 drainage system. The 48-inch reinforced concrete pipe discharging under Parker Road carries all flows upstream draining to the West Branch of Trout Brook. The culvert appears to be in good condition with an estimated capacity of 152 cfs. Based on a peak flow of 136 cfs for the conditions modeled, the culvert is estimated to have an additional 16 cfs of reserve capacity. Therefore, it appears that the culvert is adequate as it presently exists.

The 48-inch reinforced concrete pipe immediately upstream of Parker Road is located under a section of road that appears to be abandoned or used on a limited basis. Table 2-16 indicates that this culvert has a capacity of 105 cfs which is 31 cfs less than the pre-construction peak design storm flows. The culvert appears to be in good condition.

The 21-inch reinforced concrete pipe is located under a private residential drive approximately 1500 lineal feet upstream of Parker Road on the West Branch of Trout Brook. The culvert appears to be in good condition. Field observations indicate that storm flows have exceeded the capacity of the pipe and topped over the road. Based on the runoff analysis using a 25-year 24-hour storm, flows may peak to approximately 60 cfs at this point in the drainage system. The existing pipe's capacity is estimated to be 17 cfs. This culvert currently appears to be undersized, prior to any site remediation.

Several alternatives which would control excess flow were evaluated including construction of a detention basin, construction of larger culverts, and construction of a culvert parallel to the existing culvert. A detention basin located at the northwestern corner of the site with a storage of 4.97 acre feet has been incorporated into the design. This detention basin will release flows equal to the predeveloped runoff for the 25-year, 24-hour storm when a runoff curve number (CN) of 79 is used. A detailed discussion of the determination of the CN is presented below.

Subarea 2 Surface Water Runoff Control

As previously discussed, a 24-inch reinforced concrete pipe exists in the subarea 2 drainage system. Figure 2-9 indicates that the East Branch of Trout Brook discharge to a small storm system. The 24-inch culvert is located at the entrance to the system. Table 2-17 indicates that the culvert has a total capacity of 45 cfs. The remaining storm system appears to be privately installed and owned and consists of 24-inch and 30-inch reinforced concrete pipes. A 15-inch reinforced concrete pipe discharging to grade was installed at the existing drainage structure on the south side of the Parker Road. The storm sewer system's 24-inch and 15-inch reinforced concrete pipe have a combined capacity of 45 cfs.

Estimates indicate that flows to the 24" culvert under Parker Road for the pre-developed 25 year storm event are approximately 54 cfs. It appears that the system has performed sufficiently in the past. This may be attributed to natural detention behind the culvert. Estimates indicate that without detention, flows following site remediation will increase by approximately 40 cfs. It is anticipated that this additional volume will significantly impact the performance of the culvert. For this reason, a detention basin with a total storage of 5.6 acre feet has been designed to be installed in the JCP&L Right of Way on the south eastern portion of the site. This facility is sufficiently sized to discharge flows at pre-development rates for a 25-year, 24-hour storm when a CN of 79 is used.

It is noted that the analysis was performed based on design storms of a 25-year 24-hour frequency. A short term effect of a storm of greater magnitude may result in runoff sheet flow over Parker Road. It is anticipated that upstream flooding would be contained within the wetland areas and would not cause flooding of residential dwellings. Flooding would most likely be contained within the centerline elevation contour of Parker Road.

Determination of Curve Number (CN) for Runoff

The runoff curve number (CN) of 79 used to perform drainage calculations was chosen at the direction of the New Jersey Soil Conservation Service. It is likely that a CN value of 67 would be more appropriate. This opinion is based on the Soil Conservation Services "Cover Description and Curve Number Charts". The charts recommend using values in the upper 70's and low 80's for surfaces such as asphalt streets, roads and hard packed dirt. Therefore, it is believed that a more representative CN value allowing for flow resistance could have been used. By using a lower number, flow values decrease dramatically. A comparison was done between using a CN value of 79 and one of 67 for the 10 year - 24 hour storm event contributing to drainage point "C". A flow of 70 cfs was calculated for the storm with a CN of 79. By changing the value of 67, the flow as found to be 43 cfs, a reduction of approximately 39 percent. The required detention volume at this location is also affected, being reduced from 4.8 acre feet (AF) to 2.5 AF if the CN number is reduced from 79 to 67. Because of the large difference in calculated flows by using the CN value of 79, the detention basins are most likely overdesigned. In addition, the flows listed in Table 2-16 will not necessarily be indicative of actual storm flows.

<u>On-Site Detention Facilities</u>

In order to control increased runoff from the site caused by development, three on-site detention basins have been proposed. The post-developed site conditions were analyzed for the 25 year - 24 hour storm event. Runoff was directed through lined open channels to the basins. Principal and emergency spillways were designed in accordance with Sections 4.07.01 and Appendix A10 of the <u>Standards for Soil Erosion and Sediment Control in New Jersey</u>. A detention basin is located on the north side of the site and detains 0.80 AF. Discharge is directed through a 12" diameter reinforced concrete pipe (RCP) at a slope of 0.001 ft/ft to an unnamed tributary to Tanners Brook. A second detention basin is located on the southeast side of the site in the JCP&L Right of Way and detains 5.60 AF. This basin is comprised of two individual basins interconnected by a 36" dia. RCP. The purpose of the "split" facility was to provide for adequate storage while maintaining a 50' easement from powerline towers without requiring construction activities on private property or designated wetlands. This is in accordance with discussions held with the NJDEP. Outfall is via a 21" dia RCP at 0.002. This discharge is directed to the east branch of Trout Brook. A third detention basin is located on the northwest side of the site and detains 4.97 AF. Discharge is directed through a 12" diameter RCP at a slope of 0.005. Energy dissipators are located downstream of the outfall.

2.07 Site Access

Access to the Combe Fill South Landfill will be provided by a 24 foot wide gravel road from Parker Road. The maximum grade of the access road is 9.93 percent. The location of the road is shown on Sheet 4 of the Design Drawings. A 12 foot wide gravel road with a maximum grade of 9.62 percent will be constructed surrounding the capped areas and provide access to the cover system and gas and ground water collection and treatment systems. All-terrain vehicles may be used to access the capped areas of the landfill. General site access is described in Section 9.

2.08 Site Security

The Record of Decision (ROD) mandates that a security fence be installed to restrict site access. An 8-foot high chain-link fence topped with one foot of barbed wire will be installed surrounding the remediated site areas, the ground water treatment facility, and the building housing the exhausters and enclosed flare for the gas treatment and collection facility. Access to the site will be controlled by a locking gate located at the junction of the proposed paved access road and Parker Road.

Appropriate signs warning that the site is a remediated hazardous waste site will be located around the site perimeter at 50 foot intervals, or as often as required depending on the line of sight to discourage trespassers.

2.09 Summary

The design for the cap system to be placed on the Combe Fill South Landfill has been prepared to meet Federal regulations set forth in 40 CFR 264.310, State of New Jersey Regulations set forth in NJAC Subchapter 11, Section 7:26-11-4 and technical guidelines developed by the USEPA.

The preliminary design of the cap system was developed based on the analyses of the performance of the entire cap components of ten (10) proposed cap system designs. Cap performance was modeled using the HELP model. Individual components of the various cap systems were analyzed utilizing methods presented in the document "Geosynthetic Design Guidance for Hazardous Waste Landfill Cells and Surface Impoundments" prepared for the USEPA.

Utilizing the initial results of the analyses of the performance of the various cap systems and the cap system components, and the ability to meet the applicable regulations, two cap systems were selected for additional analyses. Cap system E, consisting from the surface down of six inches of topsoil, and 18 inch vegetative layer, a geotextile filter, a 12 inch drainage layer, a 30 mil synthetic liner a 24 inch soil barrier layer and a geotextile filter was recommended for installation in areas where the slopes are 1 vertical on 6.5 horizontal (15 percent) or less. Cap system F, which is identical to Cap system E with the exceptions that the synthetic liner is eliminated and a geotextile filter is incorporated between the soil barrier layer and the drainage layer, was recommended for installation over the remainder of the site where slopes will be graded to a maximum of 1 vertical on 4.5 horizontal (22 percent). Due to site constraints imposed by property boundaries, a power line right of way, and wetlands, a gabion retaining wall was designed in order to allow grading criteria to be met while minimizing refuse grading and off-site embankment material.

The additional analyses reflected modifications incorporated at the direction of the NJDEP. These included the installation of a 40 mil synthetic liner in lieu of the originally proposed 30 mil liner, and limiting the extent of synthetic liner to slopes of 10 percent or less. The analyses indicated that the proposed cap systems will meet all regulatory requirements and achieve acceptable factors of safety against sliding of cap system components. An analysis of overall slope stability and foundation stability was also performed utilizing the computer program "STABR". These analyses indicate that the proposed geometry and cover systems will provide acceptable factors of safety against slope and deep foundation failure.

In addition to the analyses of cap performance, cap components and slope and foundation stability, an investigation of the availability of construction materials was conducted. This investigation indicated that sufficient quantities of materials likely to be used in the construction of the topsoil, vegetative, drainage layers, and gabion walls appear to be available within a 35-mile radius of the site. There does not appear to be a sufficient quantity of natural soil capable of meeting the criteria for use in the soil barrier layer located within an economically feasible haul distance of the site. However, sufficient quantities of soil capable of meeting the requirements for the soil barrier layer through the addition of soil bentonite are available within an economic haul distance of the site.

An analysis of storm water runoff performed in accordance with direction provided by the Morris County Soil Conservation District resulted in the design of detention basins at two locations on the site.

SECTION 3 - LANDFILL GAS COLLECTION AND TREATMENT SYSTEM

3.01 General

The ROD for the Combe Fill South Superfund Site mandated that as part of the site closure, an active gas extraction and venting system be installed at the site. This section of the Design Report presents the basis of design for this system.

3.02 Gas Generation Rate

The rate of landfill gas generation is dependent on several factors including:

- Refuse quantity;
- Refuse composition;
- Refuse age;
- Temperature in the landfill;
- Quantity and quality of nutrients;
- pH and alkalinity of liquids in the landfill.

The generation of landfill gas is often modeled by a first order kinetic decay equation of the form:

$$L = Loe^{-kt}$$

Where:

L = Quantity of gas generated in year of interest

Lo = Steady state gas generation rate

t = Time generating at steady state rate relative to year of inter est

k = A constant which is a function of the half life of the refuse

The remedial investigation (RI) performed for this site indicated that the majority of refuse had been placed from 1972 through 1981. The RI further indicated that the average rate of refuse placement had been 45,000 cubic yards per month or 540,000 cubic yards per year. Assuming a typical unit weight for refuse of 1,100 pounds per cubic yard, this amount converts to 297,000 tons per year. This was rounded to 300,000 tons per year.

In a paper titled "Predicting Gas Generation From Landfills" by Robert K. Ham it is reported that total gas production rates may range from 3.1 to 37 liters/kilogram - year (l/kg-yr) which corresponds to a range from 1.89×10^{-4} cubic feet/ton - minute (cf/ton-min) to 2.254×10^{-3} cf/ton-min. In the interest of conservatism, the upper limit of this range was selected for these analyses. Utilizing this value and the placement rate of 300,000 tons per year, the steady state generation rate for gas placed during a given year may be calculated as 659.7 cubic feet per minute.

A paper titled "Fundamentals of Decomposition and Gas Generation in Landfills" by Grahame Farquhar indicates that it can take from 6 to 18 months for a mass of refuse to reach its steady state generation rate. An average value of one year was selected for this analysis. As an example, refuse placed during 1975 would not reach its steady state generation rate until 1976. If the year of interest is 1989, this means that the refuse placed during 1975 has been generating at a steady state for a period of thirteen years relative to the year of interest. Therefore, a t of 13 would be used in the above equation.

The final term in the equation is the constant k. This is a function of the half life (t½) of the refuse. k is determined by setting $e^{-kt} = 0.5$, substituting the half life for t and solving for k. The half life is dependent on the composition of the refuse and on the conditions under which decomposition is occurring. In Methane Generation and Recovery from Landfills by Emcon Associates, information is presented indicating that readily decomposable organics (food and grass) which may make up approximately 35% of the total organic fraction of the landfill, may have a t½ between one and nine years. The same source indicates that moderately decomposable organics, (paper, wood and textiles) which typically comprise 61% of the total organic fraction have a t½ on the order of two years. Emcon further indicates that the remaining component of the organic fraction of the landfill, refractory organics (plastic and rubber) may have a t½ between 20 and 36 years.

The values presented by Emcon compare favorably with those presented by Ham in a paper titled "Gas Quantities and Chemical Characteristics". In that paper, a half life ranging from .5 to 1.5 years is presented for readily decomposable materials while a range from five to 25 years is presented for moderately decomposable materials.

The calculations performed for this site evaluated half lives of 2, 5, 25 and 36 years. These were selected to reflect a representative range for the moderately decomposable fraction of the refuse, recognizing this fraction would likely compose the greatest portion of the refuse placed at Combe. Given the short half lives associated with the readily decomposable fraction of the refuse and the fact that more than six years has elapsed since refuse was last placed at the Combe site, this fraction of the refuse was not modeled separately. Similarly, given the small amount of organic refuse composed of refractory organics, this fraction was not modeled separately.

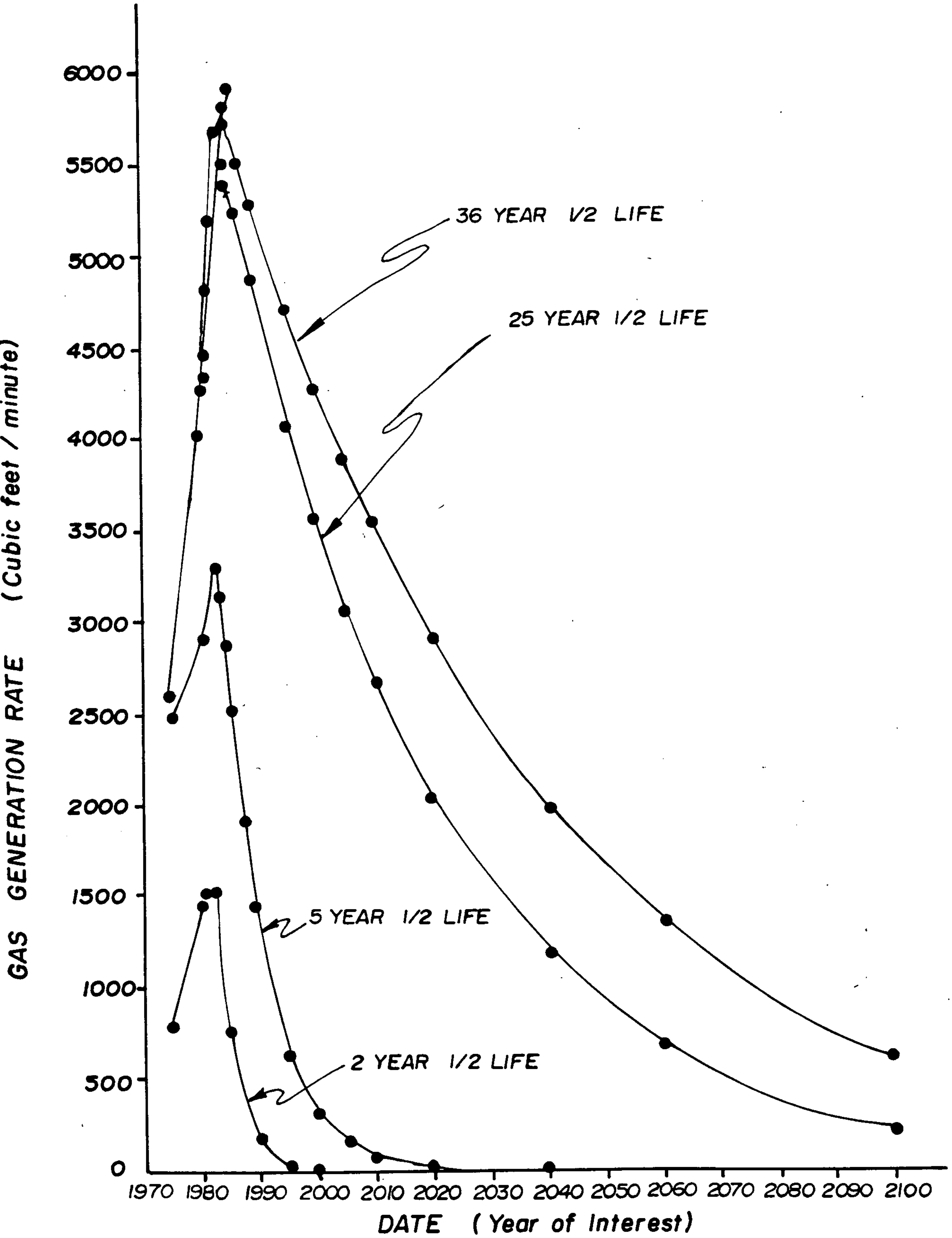
Calculations were performed by assuming a half life and solving for k. A year of interest was selected and a methane generation rate calculated for that year for each 300,000 tons of refuse placed yearly from 1972 through 1981. The generation rates in the year of interest for each 300,000 tons of refuse placed from 1972 through 1982 were then summed to provide an estimate of the total rate of gas being generated in the year of interest. Detailed calculations are included in Appendix 3-1 to this report. Figure 3-1 graphically shows the results of these analyses. For 1989, the calculated gas generation rates are as follows:

Assumed Half Life ($t_{1/2}$) (Years)	Gas Generation Rate (cubic feet per minutes)
2	198
5	1485
25	4934
36	5427

It is likely that these numbers are conservatively high. The upper limit of the stated range of gas generation rates was used to calculate these values. The analysis assumes that the entire quantity of refuse placed in a given year was moderately decomposable refuse. As previously discussed, typical refuse is composed of approximately 60% moderately decomposable refuse while 35% is composed of readily decomposable material. Given the short half-life of readily decomposable fraction and the time since refuse deposition ceased, it is unlikely that it is having a significant effect on gas production at this site. Due to the limited quantity of refractory organics, typically on the order of 4 to 5%, it is also unlikely that they are having a significant impact on methane generation.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

THEORETICAL GAS GENERATION RATE



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The following table, extracted from a paper by Ronald Lofy titled "Methane Gas Recovery/Treatment for Use as a Fuel," shows actual recovery rates ranging from approximately 350 CFM to 5,600 CFM.

Location	Area of Gas Extraction	Average Landfill Depth	Approximate Gas Extraction Rate
Azusa, CA	37 Acres	130 Feet	350 CFM
Wilmington, CA	38 Acres	60 Feet	850 CFM
Monterey Park, CA	150 Acres	250 Feet	5,500 CFM
Los Angeles, CA	36 Acres	120 Feet	2,000 CFM
City Industry, CA	120 Acres	35-40 Feet	400 CFM
Mountain View, CA	30 Acres	40 Feet	700 CFM

The information reported for these sites is circa 1979. In the same paper, information is presented regarding a landfill in Cinnaminson, New Jersey. Cinnaminson is near Philadelphia, approximately 55 miles south west of Combe Fill South. According to this article, the landfill had an area of 64 acres with an average depth of 60 feet. Refuse placement had started in 1949 and as of 1979 was continuing in one section of the fill adjacent to the area in which gas recovery is occurring. As of 1970, approximately 2.5 million tons of waste were in place. The site had a gas migration control system consisting of 97 wells in place and a recovery system consisting of 30 wells, each about fifty feet deep. The recovery system was extracting approximately 700 CFM of gas for sale to a local corporation. This information is presented in that this site is roughly comparable to the Combe Fill South Site.

An assessment of this operating data is presented in the following table:

Location	Approximate Gas Extraction Rate per Acre of Landfill Area
Azusa, CA	9.5 CFM/Acre
Wilmington, CA	22.4 CFM/Acre
Monterey Park, CA	36.7 CFM/Acre
Los Angeles, CA	55.5 CFM/Acre
City Industry, CA	3.3 CFM/Acre
Mountain View, CA	23.3 CFM/Acre
Cinnaminson, NJ	2.8 CFM/Acre

This analysis shows that the gas production rate can range from 2.8 CFM/Acre to 55.5 CFM/Acre with an average value of approximately 22 CFM/Acre. When these values are multiplied by the area of the Combe Fill South, approximately 65 acres, the predicted extraction rates range from 182 CFM to 3608 CFM with an average value of 1430 CFM. The lower end of this range is that predicted by experience at the Cinnaminson landfill which is also in New Jersey. These values predicted by experience fall within the range of values predicted by theoretical calculations.

Based on the theoretical calculations of gas generation rates, experience at other sites and input provided by the NJDEP, an optimum design recovery rate of 2,000 CFM has been selected. It is greater than the recovery rates being used at five of the seven sites for which data is reported, although it is less than the upper limits of the theoretical rates calculated for half lives of 25 to 36 years. The system will be capable of handling flows of up to 3,000 CFM, although at this extraction rate the exhausters will be operating at the upper limits of the pump curve.

As previously discussed, the theoretical rates were calculated assuming that all of the refuse was composed of a moderately decomposable fraction while it is likely that only approximately 60% has this composition. Assuming that this is the case, the theoretical rate for a given year could be estimated more accurately by taking 60% of the total calculated generation rate. This implies that for the longest half-life used in these calculations, 36 years, the 1990 gas generation rate would be approximately (.60)(5130) =3,078 CFM. A half life of 36 years represents an upper bound on refractory organics which typically comprise only 4% of refuse placed. The upper bound on the moderately decomposable fraction of 25 years corresponds to a total generation rate of approximately 4,750 CFM. Sixty percent of this value represents a likely theoretical rate of 2,850 CFM in 1990. As shown on Figure 3-1, this generation rate will decrease with time. Given the conservatism of the theoretical calculations along with the operating data from existing sites, it is appropriate to design for an optimum extraction rate of 2,000 CFM with the ability to handle a generation rate of up to 3,000 CFM.

3.03 Gas Extraction Well Spacing

Gas well spacing is determined using a radius of influence approach. This approach assumes that all gas within the radius of influence of a given well will be drawn to and vented through the well. Therefore, in order to capture all the gas being generated in the area between two wells, the spacing between the wells should be approximately twice the radius of influence for a single well.

In Methane Generation and Recovery from Landfills, Emcon presents the equation for use in estimating the radius of influence of a single well. In its transformed form, the equation is as follows:

$$R = \left(\frac{QwC^{1}/2}{K\,\Pi\,Dr}\right)$$

Where:

R = Radius of influence (m)

C = Fractional methane concentration

k = A compilation of conversion factors, 1.157×10^{-8} (l/day)/(mL/sec)

Qw = Well flow rate (l/sec)

t = Refuse thickness (m)

D = In-place refuse density.

r = Methane production rate, mL/kg/day

As reported in the Handbook of Solid Waste Management, residential wastes may have densities ranging from 89 to 750 lb/cy while industrial wastes may have densities ranging from 50 to 2430 lb/cy (excluding heavy metal scrap). A representative value of 1,100 lb/cy is taken as an average value for material deposited at Combe. Both limits of the range, as well as the representative value of 1,100 lbs/cy were used in this analysis.

The range of gas production rate has previously been presented as from 3.1 l/kg-yr to 37 l/kg-yr. Both limits of this range were utilized in this analysis.

This equation was utilized to evaluate data obtained during the gas extraction testing conducted at the site from February 13 through February 16, 1989. Testing was conducted on two wells, GT-1 and GT-2 installed by O'Brien & Gere in November of 1988. The gas extraction testing was documented in a memo dated February 23, 1989, which is included as Appendix 3-2 to this report.

Well GT-1 was installed in 40 feet of refuse. During the extraction testing, pumping rates varied from 30 to 58 cubic feet per minute, while methane concentrations ranged from 36% to 48%. Calculations were performed in a systematic manner varying refuse density, methane production rate, flow rate and the fractional methane concentration. A total of 24 calculations were performed for GT-1. The results ranged between a low end of 29 feet to an upper bound of 1468 feet, with an arithmetic average of approximately 264 feet. A radius of influence was also calculated for GT-1 using the following average conditions:

t = 40 ft

Qw = 44 CFM

C = 0.42

D = 1100 lb/cy

r = 20.05 l/kg-yr

$K = 1.157 \times 10^{-8}$ (l/day)/(ml/kg/day)

The value of the radius of influence for these conditions was calculated to be approximately 77 feet.

Well GT-2 was installed in 25 feet of refuse. During extraction testing, pumping rates ranged from 37 to 58 CFM while methane concentrations varied from 37% to 51%. A set of calculations similar to that performed on GT-1 was performed for GT-2. The calculated results for the radius of influence ranged from a low of 41 feet to a high of 1468 feet with an arithmetic average of approximately 356 feet. A radius of influence for GT-2 was calculated using the following average conditions:

t = 25 feet

Qw = 47.5 CFM

$C = 0.44$

$D = 1100$ lb/cy

$r = 20.05$ l/kg/yr

$K = 1.157 \times 10^{-8}$ (l/day) (ml/sec)

The radius of influence for these conditions was calculated to be 103 feet.

An alternate method presented in Methane Generation and Recovery from Landfills was also utilized to estimate the radius of influence. It is a simple mass balance equation which, in its transformed form, is as follows:

$$R = \frac{Q}{tDFg} + r^2$$

Where:

Q = Magnitude of gas flow across an imaginary cylindrical surface

R = Radius of influence

r = Radius of the imaginary cylindrical surface

t = Refuse thickness

D = Refuse density

Fg = Gas production rate per unit mass of refuse

The flow rate was taken as 30 CFM, the lowest flow rate utilized during the extraction testing. The radius of the imaginary cylindrical surface was taken as six inches, the radius of the installed well and gravel pack. Refuse thicknesses of 25, 40 and 80 feet were evaluated to model thicknesses encountered in wells GT-2, GT-1 and D-6 respectively. As in the previously described calculations, densities of 50, 1,100, and 2,430 pounds per cubic yard were evaluated. Gas production rates of 3.1 l/kg-yr and 37 l/kg-yr were evaluated. These were determined as previously discussed. The values calculated using this method ranged from 34 feet to 1692 feet with the eighteen calculated values having an average of 422 feet. For the average conditions of a thickness of 40 feet a density of 1100 pcy, calculated values of the radius of influence were 72 feet and 250 feet associated with gas generation rates of 37 l/kg-yr and 3.1 l/kg-yr respectively. A copy of all calculations of radii of influence are included as Appendix 3-3 to this report.

Radii of influence from 50 feet to approximately 250 feet are presented in the literature. These values are within the range calculated under the various scenarios for the Combe Site. The values presented in the literature are often for active sites on which no cover has been placed. It would be reasonable to expect that on a capped site, such as will be the case at Combe, these radii might be even greater due to the minimization of air intrusion.

Utilizing the ranges of calculated radii of influence and experience at similar sites well spacings to be utilized at Combe were determined. The well spacings will be two times the calculated radius of influence. The selected radius of influence for this site is 150 feet. Therefore, wells on the interior of the landfill will be spaced 300 feet apart. However, in order to provide an added degree of protection against off-site gas migration, wells on the perimeter of the site will be spaced 200 feet apart.

3.04 Gas Extraction System Design

The active gas extraction system is to consist of a total of 66 wells each connected to one of five headers. Each header services from 11 to 14 extraction wells in one of five sections of the landfill, with the headers being manifolded to exhausters located in the exhauster building. Treatment of the extracted gas will be provided by enclosed flame.

3.04.01 Gas Extraction Wells

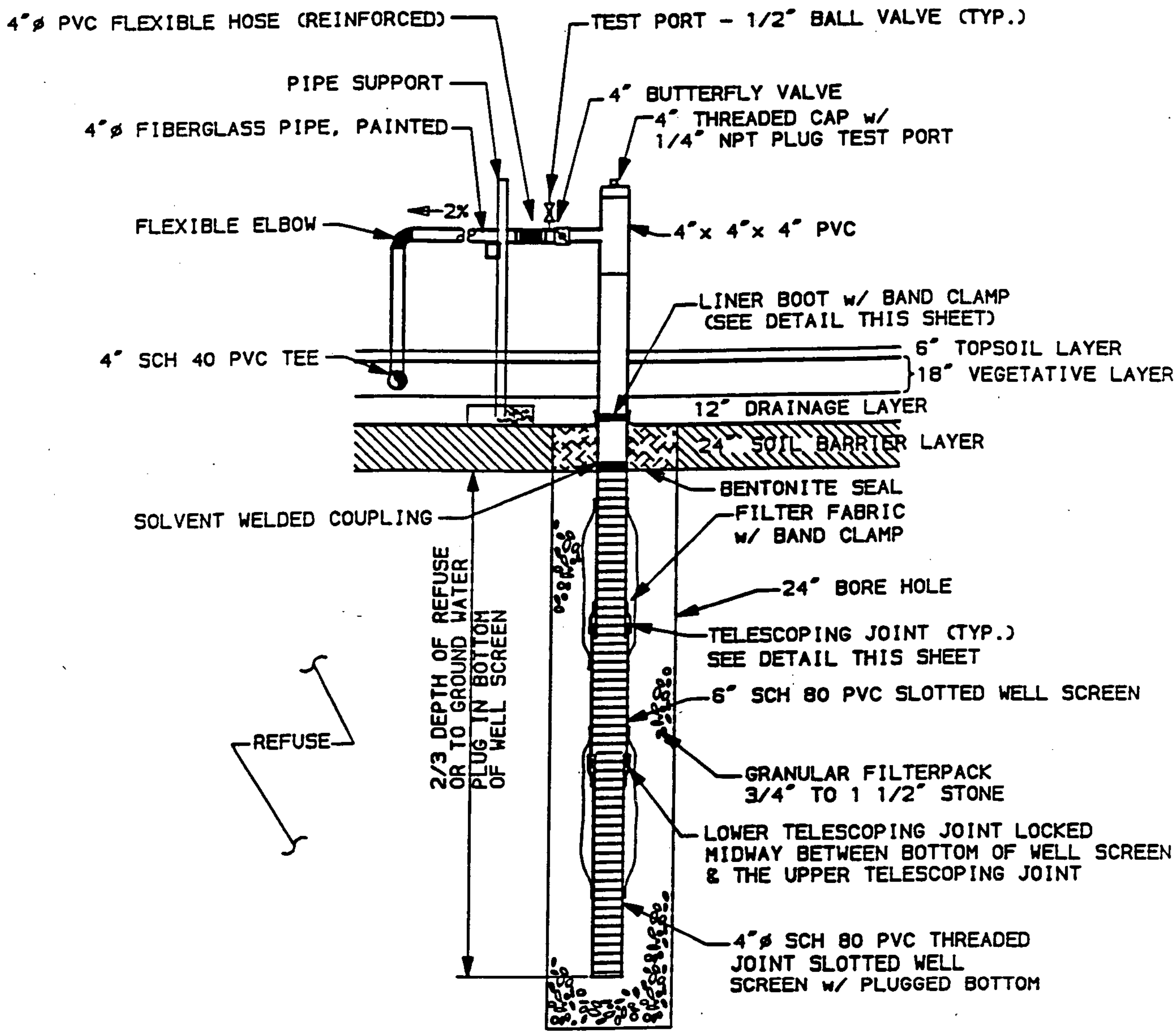
A total of 66 extraction wells will be installed utilizing well spacing as presented in Section 3.02. Thirty six perimeter wells will be installed on 200 foot centers no closer than 50 feet to the edge of refuse. The offset from the edge of refuse will minimize the infiltration of atmospheric gases. Each perimeter well will be installed to the top of the ground water table. This will serve as a positive seal against offsite migration of landfill gas.

Thirty wells will be installed on the interior of the landfill. Each of these wells will be installed to two-thirds the total depth of refuse or to the top of the ground water table, whichever is shallower.

Gas extraction wells will be installed in a minimum 24 inch diameter borehole drilled utilizing methods which will not smear or seal the borehole. The lower and upper portion of the well screen will be 4 inches diameter schedule 40 PVC pipe and the middle portion of the well screen will be 6 inch diameter schedule 40 PVC. The well casing will be 4 inch diameter Schedule 40 PVC. The 4 inch and 6 inch diameter portions of the well screen will be connected utilizing telescoping joints which will be capable of accommodating more than four feet of landfill settlement. The annular space between the well and the walls of the borehole will be filled with a gravel pack. This will serve to expand the effective radius of the well while minimizing the amount of material from the landfill drawn into the well. Well details are shown in Figure 3-2.

Gas extraction wells will be installed prior to installation of the soil barrier layer of the cover. This will permit refuse removed from the borehole to be disposed of on site, will provide passive venting during installation of the soil barrier layer and the flexible membrane portion of the cover, and will allow the soil barrier layer to be covered relatively soon after installation, thus minimizing desiccation. When the cap is placed, a seal will be made between the two foot soil barrier layer and the well casing utilizing bentonite. In portions of landfill where wells penetrate the LDPE liner, the liner will be formed into a boot and sealed to the well casing utilizing a band clamp.

Each well will have a butterfly valve in order that the well may be balanced for its optimum extraction rate and, if necessary, isolated for repairs and maintenance. As discussed in Section 3.04.02, the extraction wells will be connected to either below ground or above ground header pipe, depending on their location in the landfill. Gas extraction wells connected to below ground piping will be plugged at grade with four inch diameter threaded cap. Each cap will have a 1/4 inch plug fitting to be utilized in measuring negative pressures at the well head. A four inch butterfly valve with a 1/4 inch plug fitting on each side of the valve for measuring negative pressure will be connected to the extraction well in the one foot cap drainage layer. The well header pipe will connect to the main gas header using a tee coupling. A short length of flexible hose will be utilized to minimize the stress between the well



GAS EXTRACTION WELL

NOT TO SCALE

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casing and the header pipe due to settlement. A fiberglass marker will be installed next to each well to facilitate its location.

The portion of gas extraction wells to be connected to above ground piping extending above grade will be four inch diameter, schedule 40 PVC.

The above ground portion of the well casing will have a tee fitting with a four inch threaded PVC cap. A four inch butterfly valve will be connected to the tee fitting. A ¼ inch plug fitting will be provided for measurement of negative pressure at the well head on both sides of the four inch butterfly valve. The butterfly valve will have a removable or locking actuator handle to prevent unauthorized use of the valve which could disturb the balance of the extraction system. A short length of flexible four inch diameter hose will connect the valve to the header system. This will minimize stress on the header system due to settlement and minimize stress on the well system due to expansion and contraction of the header pipe.

3.04.02 Gas Extraction Piping

Design considerations associated with the gas extraction header include the following:

- Accommodation of settlement to minimize breakage or plugging of the gas header;
- Appropriate sizing to minimize friction losses;
- Ease of operation and maintenance;
- Minimization of vandalism;
- Collection of condensate;

- Cost effectiveness.

As discussed in Section 2.03.03 although the major portion of landfill settlement will have likely occurred prior to closure, a certain amount of continuing settlement may be anticipated due to the additional weight of the cap, consolidation under load, sporadic movement of fine material into voids in the fill and chemical and biological decomposition. Experience at other landfills has demonstrated that gas collection piping installed below grade on flatter portions of the site may be susceptible to damage from settling. The damage may range from plugging due to the collection of condensate in dips in the collection piping to breaking of the collection piping. At a closed landfill, such as Combe Fill South, repair of the collection piping may require excavation through the low permeability cover, possibly compromising its integrity. Therefore, the gas extraction header piping at Combe Fill South is designed to accommodate continuing settlement utilizing a combination of below ground and above ground piping.

Below ground piping will be utilized in areas of the landfill with completed slopes greater than 10%. At this grade sufficient slope is provided to accommodate settlement and still promote flow of condensate. Areas of the landfill with grades in excess of 10% also represent areas nearer the perimeter of the fill where refuse thickness is less than at the center and hence will be subject to less settlement.

Materials considered for use in the underground piping included high density polyethylene (HDPE), fiberglass, steel, and PVC. PVC was selected since it is chemically compatible with known chemicals in the landfill in dilute considerations, has a wider selection of fittings and coupling than HDPE and is more economical than steel or fiberglass. PVC has been used widely in the construction of landfill gas extraction systems.

Below ground piping will be installed in the one foot drainage layer. A structural analysis of buried PVC gas piping is included as Appendix 3-4. In order to protect buried gas piping during construction, a temporary berm will be placed to a minimum thickness of 12 inches over the piping. Installation of the pipe at this depth, coupled with the temperature of the landfill gas being extracted (typically between 50 and 70 degrees Fahrenheit) will be sufficient to prevent freezing of condensate. In addition, installation of the pipe in the drainage layer will prelude damage to the synthetic liner and soil barrier layer should the pipe require excavation for repair. All underground piping will have a trace wire to facilitate its location.

At slopes of less than 10% epoxy reinforced fiberglass piping will be installed above ground. The area of above ground piping will be concurrent with the area covered by the LDPE geomembrane.

Epoxy reinforced fiberglass piping was selected in lieu of PVC, HDPE and steel. Fiberglass piping has a lower coefficient of expansion than PVC or HDPE and requires fewer pipe supports. It was chosen over coated steel piping because it is more economical, does not present problems associated with corrosion, and is easily repaired if damaged by vandalism. Epoxy reinforced fiberglass piping can undergo changes in appearance when exposed to sunlight. This is a surface phenomenon caused by ultraviolet degradation of the resin. The rate of appearance change depends on the time of exposure and the intensity of the sunlight. If surface resin is severely degraded, glass fibers on the surface of the outer diameter will be exposed. Further degradation is prevented by the ability of the glass to absorb ultraviolet light and prevent damage to the remainder of the pipe wall. If surface degradation occurs, it will have little effect on performance of the piping system. Fiberglass piping does require more pipe supports than steel piping as well as having a greater coefficient of expansion.

Coefficients of expansion for the pipe materials considered are as follows:

Pipe Materials	Coefficient of Expansion and Contraction (Inches/100 Feet of Pipe/120°F Temperature Change)
HDPE	17.5
PVC	6.5
Fiberglass	1.26 to 1.95
Steel	0.3 to 0.8

While the coefficient of expansion of fiberglass piping is greater than the steel piping, it is significantly less than HDPE and PVC piping. Expansion loops will be installed in the pipe proportional to the length of pipe run. Concrete anchors will be installed at both ends of the pipe run where the transition between above ground and below ground piping is made and at the landfill crest.

The above ground fiberglass piping will require pipe supports approximately every 17 to 23 feet, depending on the pipe diameter. This is contrasted to a spacing of approximately from 6 to 12 feet for HDPE, 6 to 14 feet for PVC and 19 to 31 feet for steel. The pipes will be supported on adjustable supports constructed of pressure treated wood. The supports are adjustable so that the pipe may be raised or lowered to accommodate landfill settlement so that drainage of condensate will be maintained. Piping will be kept a minimum of 18 inches above grade to allow access for mowing.

The gas collection system header pipes vary from four inches to 8 inches in diameter in two inch increments. Smaller diameter pipe is used at the end of the header furthest from the exhauster, and increases as more wells discharge to the header. The size of the header in a given area was determined to minimize head losses associated with pipe friction. Piping sizes were determined utilizing the maximum anticipated pumping rate per well of 50 CFM, and a friction loss of between less than 0.01 and 0.03 PSI per 100 feet of pipe depending on pipe diameter and the number of wells discharging to that portion of the header. Gas extraction system pressure drop calculations are included as Appendix 3-5. Piping has been sized so that there will be less than eight inches of water column lost between the two most widely separated wells on a given header. This minimal amount of friction loss will permit the system to be balanced so that the two most widely separated wells on a given header can have the same vacuum.

Valve boxes will be installed at major branches in the header system. This will aid in balancing sections of the header system and will allow a section of the system to be shut down for repairs without the need of shutting down the entire system. These will also provide access to facilitate cleaning of the header system should it become necessary. Test ports will be provided on each side of the valve to facilitate balancing of the system.

3.04.03 Gas Extraction Exhausters

Exhausters for use with the gas extraction system must be capable of providing a suitable vacuum at each well while accommodating friction losses in the piping and providing flexibility in operation and maintenance.

As previously presented, each header will cause friction losses of less than eight inches of water. The total negative pressure required for each header and well system will be on the order of 15 inches of water column at the exhauster. The elevation of the exhausters will be at approximately 840 feet above sea level.

In addition to meeting the above technical criteria, the selected system of exhausters must provide for reliability and flexibility in operation and maintenance. One exhauster may not provide the flexibility needed to match the exhauster system to the actual gas production rate. Multiple exhausters, although more expensive, provide the flexibility to cover a wide range of gas production. Three exhausters will be manifolded together with a fourth exhauster for standby. The three exhausters are sized for a maximum extraction rate of 3000 CFM and an expected rate of approximately 2000 CFM. If the rate of gas production varies over the landfill due to the age of refuse, refuse thickness, or other reasons the exhausters may be adjusted. In the event that gas production drastically decreases, it may be possible to operate two or even one exhauster for the entire system. If there should be a blockage or break in one of the headers, the remaining gas extraction system could compensate for some of the loss in extraction capacity.

Centrifugal exhausters were chosen in lieu of positive displacement exhausters. Centrifugal exhausters allow the flow rate to be varied by throttling, maintain their efficiency as parts wear, are usually direct driven rather than belt driven, and are easier to maintain. A total of four identical exhausters will be provided; three operating exhausters and a fourth, spare exhauster.

Each exhauster is sized to handle from 300 to 1000 CFM of landfill gas. Excess pumping capacity will be available. Each exhauster will be powered by a 230/460 volt, 15 horsepower explosion proof electric motor. The exhauster impeller and other operating parts will be coated with a phenolic coating to minimize corrosion.

Piping on the inlet side of the exhausters will be manifolded to permit ease in utilization of the spare exhauster or the operation of multiple headers on a single exhauster. Piping on the outlet side will also be manifolded to permit flexibility in discharge to the selected gas treatment system. Butterfly valves with valve stops will be utilized for throttling and isolating sections of the piping. Fittings will be included to allow monitoring of gas volume, pressure and gas composition.

3.04.04 Condensate Collection

As warm landfill gas cools upon extraction water vapor contained in the gas condenses to form a liquid. Although regulatory requirements are somewhat unclear, condensate has often been considered as a hazardous waste. As such, it may not be returned to the landfill.

A literature review indicates that landfill gas may hold between 400 and 1,600 gallons of condensate per 1,000,000 cubic feet of extracted gas. In a paper title "Landfill Gas Condensate and Its Disposal", Ronald J. Lofy indicates that a conservative design number is 1,400 gallons of condensate per million cubic feet of gas extracted. Utilizing this value it can be seen that, at the design extraction rate of 2,000 CFM, approximately 4,000 gallons per day of condensate will be generated.

The gas extraction system has been designed so that condensate may be collected and discharged to the ground water treatment system. All lateral piping from the extraction wells to the headers will be sloped toward the header so that condensate will not drain back to the well. The laterals will empty into the top of the extraction headers. All extraction headers will slope at a minimum of 0.5% toward a condensate collection manhole or vault from which it will be drained by gravity. At the lowest point of the extraction header at the center of the condensate collection manhole or vault, a one inch diameter PVC pipe "J" tube will automatically drain the header pipe while having a sufficient length (20" minimum) to prevent outside air from being drawn into the gas extraction system. The "J" tube will be equipped with a one inch ball valve and a union to facilitate cleaning should it become plugged.

Condensate will drain from the collection manhole or vault via gravity to one of two pump stations. When there is a length of condensate drain line in excess of 400 feet between a condensate collection manhole and a pump station, access cleanouts will be placed to reduce the minimum length of condensate drain line to 400 feet or less in order to facilitate cleaning of the condensate drain line.

The first pump station will receive condensate produced by gas extraction from 20 gas extraction wells. It is estimated that this may represent a quantity of approximately 1,200 gallons per day. The second condensate pump station will receive condensate produced by gas extraction from the remaining 46 wells, a quantity estimated to be 2,800 gallons per day. The condensate pump stations will consist of a concrete manhole with a capacity of 500 gallons.

Condensate pumps are sized as follows:

	Pump Station Number 1	Pump Station Number 2
Static Head	37 feet	67 feet
Total Head	69 feet	87 feet
Gallons/Minute	67	88
Motor	3 BPH, 230 volt, 60 Hz, 3 phase, 3480 RPM	5 BPH, 230 volt, 60 Hz, 3 phase, 3480 RPM

Each pump station will consist of duplex submersible pumps with guide rails. Controls will consist of high level alarm, lag pump on, lead pump on, pump off, redundant pump off with low level alarm, and pump alternating switch. The pumps, piping, guide rails, and miscellaneous fittings will be constructed of 316 stainless steel. Condensate collected in the pump stations will be pumped through a valve box to a three inch HDPE force main which will discharge to the ground water treatment system.

3.04.05 Gas Extraction Building

The gas extraction exhausters along with electrical controls, sediment traps, condensate drip traps, ancillary piping, valves, and fittings will be housed in the gas extraction building. This location places the extraction building adjacent to the ground water treatment plant. Given the area available for construction of these facilities, this arrangement provides for efficient use of available land, placing the extraction building proximal to the ground water treatment plant while still providing a separation of the two processes. This will allow access for maintenance to both facilities without having activities at one facility interfere with activities at the other.

The extraction building will be a pre-engineered, metal structure designed with blow off panels, A separate, block room will house electrical controls for the exhausters with the exception of the control panel for the enclosed flare, which will be mounted adjacent to the flare, outside the building. The building will be continuously ventilated and will incorporate a methane detection and alarm system.

According to the New Jersey Uniform Building Code, which references the BOCA National Building Code, this structure will be classified as "Use Group "H" - High Hazard" (Section 306.1 of BOCA). Both BOCA and the New Jersey Uniform Building Code (Section 1002.7) require that buildings classified in Use Group "H" include a fire suppression system. Recognizing that there will be nothing flammable in the building, electrical equipment will be explosion proof, and that the building will be continuously ventilated and will have a methane detection and alarm system, a New Jersey official responsible for enforcing the code was contacted to determine the applicability of the suppression requirements to this structure. This official indicated that although a variance from the requirement from a suppression system can be sought, he had not seen such a variance granted during this 13 years of experience. In light of the code requirements and the information supplied by the code official, a sprinkler system has been incorporated into the design of the building. Interlocks will shut off the blowers if the sprinkler system is activated.

Prior to entering the exhauster building, buried gas extraction header pipes will be brought above ground utilizing a transition manhole. This transition will prevent the possibility of gas migrating along the pipeline and entering the building at the point of entry of the gas headers.

Condensate collection and transmission to a condensate collection manhole is accomplished by two methods inside the exhauster building. On the inlet (vacuum) side of each exhauster there will be a manual sediment/condensate trap which will remove the majority of condensate. The traps will each discharge by gravity to a condensate drain. The condensate drains will be manifolded together and condensate will flow by gravity through a four inch PVC pipe to the condensate collection manhole located east of the power line right of way. On the discharge side of the exhausters, condensate will be collected by automatic drip traps and discharged to the four inch PVC condensate drain previously described.

An eight foot high chain link fence topped with one foot of barbed wire, for a total height of eight feet, will surround the entire exhauster building, the pipe transition manhole and the enclosed flare described in Section 3.05. Two twelve foot wide gates will allow vehicular access for servicing the exhauster building and the equipment within the fenced area.

Construction Material - Condensate Compatibility

In the collection process of the landfill gas, condensate is generated as a result of temperature differences between the landfill gas and ambient air. The vapors in the landfill gas condense and form a two-phase condensate; an aqueous phase and an organic phase. The organic phase generally consists of 0.5-5% of the total liquid. The organic phase typically contains the following chemical compounds: hydrocarbons, xylenes, chloroethanes, chloroethenes, benzene, toluene, other priority pollutants, and traces of moisture. Estimated landfill gas condensate characteristics may include:

Parameter	Value
BOD5	10,000 mg/l
COD	20,000 mg/l
TOC	10,000 mg/
TSS	LT 25 mg/l
Total Metals	LT 0.25 mg/l
VOC	10 mg/l
Total Phenolics	10 mg/l

LT = Less Than

As shown in the above table, the condensate contains very small quantities of these chemical compounds.

The design currently calls for the following materials to be in contact with the condensate:

- Polyvinyl Chloride (PVC) Pipe

- Epoxy Resin Fiberglass Reinforced Pipe
- Epoxy Coated Steel Pipe
- 316 Stainless Steel Butterfly Valves
- Phenolic Coated Exhausters
- Concrete Condensate Collection Manholes
- 316 Stainless Steel Submersible Pumps
- HDPE Force Main

These materials in the landfill gas collection system were selected based on their use in similar applications and their reported resistance to chemicals likely to be in the condensate.

3.05 Gas Treatment System

In order to select an appropriate gas treatment system, gas samples were collected from the Combe Fill South Superfund Site from February 13-16, 1989. This sampling effort is documented in the memo included as Appendix 3-2 to this report. This section presents the results of the analyses of the gas sample and a proposed gas treatment system. A discussion of the likelihood of energy recovery is also presented.

3.05.01 Gas Composition

Scott Environmental Technology, Inc., acting as a subcontractor to O'Brien & Gere Engineers, Inc., collected gas samples at the Combe South Landfill on February 15, and 16, 1989. Samples were analyzed for the following parameters:

Methane (CH_4)

Carbon Dioxide (CO_2)

Oxygen (O_2)

Nitrogen (N_2)

Carbon Monoxide (CO)

Total Mercaptans/H_2S (H_2S)

Total Volatile Chlorinated Organics (TVCl)

Volatile Organics Analysis (COA)

Higher Heating Valve (HHV)

Sampling results as reported by Scott are included as Table 3-1. The following table contrasts the average results obtained at Combe with typical valves reported in the literature.

	Combe Fill South	Typical Landfill Gas
CH_4	47.5%	40 - 70%
N_2	34.0%	2 - 10%
CO_2	12.6%	30 - 70%
O_2	5.6%	1 - 5%
CO	LT 1.0%	0 - 1%
H_2S	0.0003% (3.4 ppm)	0.05 - 0.1%
TVCI	0.004% (25.36 ppm)	0.005 - 0.05%
HHV	477	350 - 500

Note:
- H_2S is total mercaptans and hydrogen sulfide, reported as H_2S.
- TVCl is total volatile chlorinated organics, reported as methylene chloride.
- HHV is higher heating value, BTU/scf (medium energy gas = 400-600 BTU/scf, high energy gas = 950-1000 BTU/scf)

The percent methane (CH_4) in the landfill gas is relatively high, showing promise for recovery and reuse. Generally, methane concentrations greater than 35% are attractive for energy recovery as discussed in Section 3.05.03.

The range of N_2 concentrations suggest that some atmospheric gas may have entered the well due to short circuiting, as expected for an uncapped landfill. The first two samples for well GT-1, GT 1-1 and GT 1-2, were withdrawn from the well without the blower operating. These samples contained 8% N_2 which is within the expected range. All other samples were withdrawn from the wells with the blower operating. Short circuiting could have occurred due to the absence of low permeability cover material. The effect of limited short circuiting would be to dilute characteristic landfill gas components with nitrogen. Oxygen would be readily absorbed in the soil matrix, reducing the oxygen to nitrogen ratio. The results in Table 3-1 show typical concentrations of gas components for open landfills. Short circuiting would not occur after placement of the low permeability landfill cap.

The CO_2 levels appear to be low. Most anaerobic digestion processes in a landfill tend to generate equal to slightly less amounts of CO_2 as compared to CH_4. An average ratio of 5.4 CH_4/CO_2 is higher than expected. Short circuiting of air into the well is one explanation for low CO_2 levels. However, low CO_2 concentrations are advantageous for methane recovery options.

The amounts of O_2 in the gas was slightly increased due to entering air. The O_2 concentration is expected to decrease to less than 2% after the

TABLE 3-1

LANDFILL GAS ANALYTICAL DATA

COMBE FILL SOUTH LANDFILL
MORRIS COUNTY, NEW JERSEY

Sample ID	% CH4	% 02	% N2	% CO2	% CO	ppm H2S	ppm TVC1	HHV
GT 1-1	66.7	2.0	8.0	20.0	<1.0	14.9	41.37	689
GT 1-2	68.7	2.0	8.0	21.3	<1.0	15.9	44.76	687
GT 1-3	48.7	3.4	27.2	21.2	<1.0	2.31	18.22	484
GT 1-4	50.0	3.2	28.9	177.9	<1.0	3.26	36.60	500
GT 1-5	46.8	4.9	34.0	14.3	<1.0	1.74	21.12	468
GT 1-6	45.0	4.6	32.5	17.9	<1.0	2.50	18.99	450
AVERAGE	54.3	3.4	23.1	18.8	<1.0	6.77	30.19	546
GT 2-1	46.7	6.9	39.2	7.2	<1.0	ND	27.52	467
GT 2-3	40.1	6.9	43.4	9.6	<1.0	ND	19.05	401
GT 2-4	40.1	6.9	43.4	9.6	<1.0	ND	18.02	401
GT 2-5	38.3	9.2	49.4	3.1	<1.0	ND	16.98	383
GT 2-6	38.3	9.2	49.4	3.1	<1.0	ND	21.1	383
AVERAGE	40.7	7.8	45.0	6.5	<1.0	ND	20.53	407
OVERALL AVERAGE	47.5	5.6	34.0	12.6	<1.0	3.4	25.36	477

Notes:

1. TVC1 is total volatile chlorinated organics, ppmv, expressed as methylene chloride.
2. HHV (higher heating value) of the gas is based on methane content, BTU/scf.
3. PPM H2S is a total mercaptans and hydrogen sulfide, expressed as PPM H2S.
4. ND indicates Not Detected.
5. Average gas temperature = 70 degrees Fahrenheit.
6. Samples collected 2/15/89 to 2/16/89 from gas extraction test wells GT-1 and GT-2.

landfill is capped. Carbon Monoxide (CO) was not detected at a detection limit of 1%. This is consistent with typical landfill gases.

Reduced sulfur compounds (H_2S) were detected at an average concentration of 4 ppmv. This is lower than most landfill gases, but could require pretreatment prior to use of the gas. In addition, H_2S is corrosive and could attack construction materials, but at the observed H_2S levels exotic materials of construction are not warranted. The total sulfur load from the landfill gas is low and may not require the installation of acid gas treatment systems for odor or air pollution control.

Total volatile chlorinated organics, measured as methylene chloride, averaged 25 ppmv. This value indicates that chlorinated compounds are being exhausted with the landfill gas. The results of the GC/MS scans of the sampled landfill gas indicate that vinyl chloride is the significant chlorinated organic present. Analyses detected vinyl chloride in wells GT-1 and GT-2 at an average concentration of 1.0 and 1.5 ppmv, respectively. The overall average concentration of vinyl chloride was 1.3 ppmv. Methylene chloride was detected twice at an average of 3 ppmv, however, these inconsistent data could be considered trace laboratory contamination. The discrepancy of 1.3 ppmv vinyl chloride versus 25 ppmv TVC1 could be due to method accuracy and interferences by trace compounds.

Treatment for volatile chlorinated organics does not seem warranted due to the low levels observed. Direct discharge could be possible, however a treatment system such as flaring should destroy a sufficient quantity of vinyl chloride. An acid gas treatment system is not justified based on the sampling data presented.

Trace compounds in typical landfill gas include paraffin hydrocarbons, aromatic and cyclic hydrocarbons, hydrogen, and others. Treatment or disposal options such as flaring are usually sufficient to adequately treat these trace constituents.

The gas higher heating value is a measure of the energy of the gas for fuel. Natural gas (CH_4 and H2) HHV is 950 - 1100 BTU/scf. Since typical landfill gas averages 475 BTU/scf, the gas sampled appears average. However, if the assumption that air was diluting the samples, the apparent HHV is low, and the estimated value will increase. Any increase in the heat content would make energy recovery an attractive option for this landfill gas.

3.05.02 Gas Treatment

Due to the presence of odorous compounds and the BTU content of the landfill gas being generated at Combe Fill South, some form of treatment prior to discharge of the gas will be required. During preliminary design, it was proposed that an open flare be used to treat the waste gas in order to destroy combustibles and contaminants. Upon review of the preliminary design, the NJDEP specified that an enclosed system be utilized in lieu of an open flare. A memorandum dated August 10,1989 from the New Jersey Department of Environmental Quality to the Bureau of Site Management contained this recommendation. The memorandum contained a policy statement presenting the requirements necessary for an enclosed flare system. These include the following:

i. 95% minimum NMHC reduction efficiency, 1 hour average

ii. 100 ppm CO at 7% O2

iii. Auto relighting, and auto shut off of flow of gas to the flare when combustion ceases and cannot be restarted with auto relighting

iv. Combustion-air damper system that acts to maintain stack temperature

v. Auxiliary fuel to maintain temperature is required if enclosed flares do not demonstrate acceptable VOS and/or CO emissions, or if there is insufficient methane to sustain combustion.

Enclosed gas flare systems were evaluated relative to their ability to meet the above criteria.

An enclosed gas flare, or thermal oxidizer, would have a series of burners arranged within an enclosure comprised of steel panels. The burners can be staged, when required, for larger flow ranges or unstaged for operational simplicity. The enclosure would consist a combustion chamber which provides heat and retention time to destroy gaseous waste materials. Pilots, requiring supplemental fuel (approximately 40 cf/hr), are located within the chambers in order to ensure that the burners are lit whenever required. The pilot status can be monitored using thermocouples or optical sensors and ignition of the pilots is achieved by either a manual or automatic flare control panel. Appropriate control circuitry alters the rate of supplementary fuel entering the furnace to maintain the desired combustion chamber temperature. Although it is not believed that supplementary fuel is required for system operation at this time, the system is designed for future addition of supplementary fuel if necessary. The enclosed gas flares are used for two primary reasons; to hide all or part of the flame, and to meet air emission limits.

An enclosed flare can also be configured as a thermal oxidizer. In this configuration, chambers provided with supplemental fuel burners, which provide heat and retention time to destroy gaseous waste materials. A thermocouple in the combustion chamber measures temperature. These enclosed flares are applicable for most gaseous waste and are used for odor control, toxicity elimination and visible emissions control.

Information on landfill gas quality and NJDEQ requirements was supplied to vendors of enclosed flares in both configurations. This included both the information specific to Combe Fill South and the typical landfill gas characteristics presented in the table in Section 3.05.01. Based on this information, the vendors indicated that a typical enclosed flare would include the following components:

- Vertical cylindrical steel shell
- Modular ceramic fiber lining
- Gas burner system with flame arrestor(s) at inlet
- Automatic louvered air dampers
- Natural gas pilot with electric ignitor
- U. V. flame monitor
- Auxiliary fuel gas control train
- Local control panel

The combustion chamber would have a sensing element and temperature controller. The temperature is maintained by the output of the controller being split ranged. Primary control is provided by air dampers and secondary control is provided by the addition of auxiliary fuel. The pilot(s) are equipped with automatic ignition and re-ignition and the control panel has dry contacts for initiation of blower shutdown.

An enclosed flare with these components would have a minimum 95 percent combustion efficiency. At full load, carbon monoxide levels will be a maximum of 100 ppm emission levels at 7% oxygen. The vendor supplied the following information:

Process Specifications:

Design Gas Flow Rate -	Up to 3,000 SCFM
Fume Temperature -	-30 to 120 F
Waste Gas Pressure -	1 PSIG
Combustion Temperature -	1500 F
Minimum Residence Time -	1 second

Mechanical Specifications:

Overall -	30"OD x 20' of length
Stack Dimensions -	8"OD x 35' of height
Combustion Chamber and Stack Wall -	Carbon steel
Refractory Lining -	Ceramic blanket with rigidizer coating
Inlet/Outlet Connections -	Carbon steel ring flanged
Surface Finish -	Commercial sandblasting with one coat of inorganic primer
Approximate Weight -	5000 lbs

This system would include all necessary instrumentation and controls for safe operation and the system is designed for unattended operation. Interlocks are listed below:

- Flame Failure
- Low Combustion Air Pressure
- High Temperature
- Low Temperature

A local explosion proof control panel would be included for burner management. The control panel and piping for controls would be preassembled and mounted on the mounting skid. Controls would be designed to meet explosion proof requirements.

The estimated price for this system is approximately $75,000. This price includes the following items:

- Combustion Chamber
- Burner
- Pilot and Ignitor
- Controls and Accessories
- Control Panel plus Piping Trains (Skid Mounted)
- Documentation for Installation, Operation and Maintenance

The estimated price does not include the following items:

- Foundations
- Installation of the System
- Interconnecting Piping
- Any Taxes
- Freight Costs

The design parameters of the enclosed flare meet the air pollution control regulations for landfills as outlined in the New Jersey Department of Environmental Protection memorandum.

<u>3.05.03 Alternate Uses of Extracted Landfill Gas</u>

Available options for the use of landfill gas extracted from the Combe Fill South Landfill include the following:

- Direct sale of gas to a customer;
- On-site generation of electric power;
- Injection of recovered landfill gas into an existing natural gas pipeline;
- Conversion of ~~the~~ landfill gas to other chemical forms;

Each option varies in the amount of effort required to produce the end product and in capital cost. In evaluating potential uses, the preferred use will be dictated by site characteristics, utility needs, specific market needs, regulatory constraints, and economics.

<u>Direct sale of gas to a customer</u>:

Prior to selling medium BTU gas off-site to industrial customers, some on-site gas processing would be required. At a minimum the pretreatment processing of the gas would consist of the removal of water vapor, sulfides and organic sulfur, chlorinated compounds, trace contaminants, and possible compression of the gas to elevate the pressure. A compression process may be needed to provide additional pressure head to move the gas to its use point.

On-Site Generation of electric power:

Electricity can be generated on-site using one of the following three methods; a steam turbine, a gas turbine, or a gas engine. The steam turbine requires the generation of steam to operate. A boiler would be used to generate the steam to operate the steam turbine. A compressor may be needed to boost the pressure head to the level necessary to operate the boiler. The steam turbine in turn would generate electricity. A use for the steam must be present before this system is considered to be economical. However, a market for steam does not appear to be present at this site.

The gas turbine requires the removal of visible moisture and any particulates from the gas along with compression before the gas can move through the gas turbine combustion chamber. The compressor stage is required before the turbine since the injection pressure is in the range of 10 to 20 bars. One significant disadvantage of this system is that the system efficiency is very low because of heat loss. The efficiency can be improved if the heat loss from the combustion is captured for heat use such as steam production.

The internal combustion engine requires, at a minimum, the condensate and particulates are removed. The gas is first injected under pressure into an internal combustion engine whose calibration is modified to deliver the proper percent of air to initiate combustion. A compressor may be needed to boost the pressure to the appropriate pressure head before the gas is transmitted to the engine. The motor runs a generator to develop electricity. If the thermal heat of combustion falls below the appropriate limit, a dual fuel engine can be utilized, with natural gas, propane, or diesel fuel being utilized as supplementary fuels. The internal combustion engine system has the following advantages over the gas turbine system: (1) lower capital costs, (2) less compression before injection to the engine, and (3) higher efficiency results because of the decreased energy requirements for compression.

Injection into an existing natural gas pipeline:

Landfill gas can be upgraded to yield a variety of heating values by many conventional processes, such as absorption, adsorption, membrane separation, cryogenic processes, and other additional processes. The cost of upgrading rises dramatically as the number of impurities are separated from the methane. The end product can be essentially pure methane. The particular upgrading system will depend on the needs of the end users. The cost of upgrading the gas to pipeline quality gas is an expensive process, but the end product would be able to be used by gas transmission companies and utilities and other natural gas users. The pipeline quality gas, however, can produce the greatest price premium. The carbon dioxide may also be sold for additional savings if it can be removed in a relatively pure state and a market exists.

Conversion to other chemical forms:

The landfill gas can be converted to other chemical forms, such as; methanol, ammonia, or urea. The conversion to methanol is the most economically feasible option of the three chemical processes. The water vapor and carbon dioxide must be removed from the high methane content gas prior to it being converted to methanol. The gas must also be compressed, reformed and catalytically converted. The conversion process tends to be expensive and is not, therefore, economically feasible for this particular application.

Regardless of the alternate use selected, some additional treatment of the landfill gas would be required. As a minimum, water vapor would have to be removed from the gas stream. The most common methods of removing the water vapor from the extracted landfill gas are absorption, adsorption, and condensation.

The most commonly used absorption methods are the glycol dehydration processes where diethylene glycol and trimethylene glycol are used for glycols. The process unit absorbs water vapor continuously from the gas stream by countercurrent contact with a highly concentrated glycol stream in a packed or bubble tray column. The glycol solution can be regenerated by using an inert gas stripper and applying heat or by means of vacuum regeneration.

The adsorption method is designed to dry the gas by means of contacting it with a solid desiccant. The water vapor is absorbed to the surface of the solid desiccant by means of chemical bonds from a reaction through formation of loose hydrated compounds or means of physical force. Desiccants commonly used are: silica gels and beads, alumina, activated bauxite, and molecular sieves. The typical dehydration unit consists of two vessels both filled with desiccant, the first unit is used for dehydrating while the second unit is regenerating. Regeneration is performed by passing hot gas through this second unit.

The condensation method is a mechanical process by which the water vapor is removed from the gas stream by means of compression and/or cooling. Condensation occurs when the saturated vapor comes in contact with a surface whose temperature is below the saturation temperature. The condensation process consists of the following components; first the gas is compressed, cooled, and then the gas and the condensed water are separated in a knockout drum.

In the applications where high BTU gas is to be produced, the gas will have to be upgraded by one of the following carbon dioxide removal processes; absorption into a liquid, adsorption on a solid, membrane separation, cryogenic separation, or converting to another chemical compound.

The absorption process involves the transfer of a substance from the gaseous to the liquid phase through the phase boundary. Absorbed materials are either physically dissolved in the solvent or react with it in some manner. The physical absorption process consists of dissolution of carbon dioxide in water or solvent. The solvent treatment method also has a degree of hydrogen sulfide removal attained with it.

The adsorption processes involve the transfer of a substance in a gas stream to the surface of a solid material. The following compounds can be removed by adsorption processes; carbon dioxide, hydrogen sulfide, moisture, and other impurities depending on the absorbent. The membrane separation processes selectively transport various components through membrane. Polymer membranes are used to selectively remove carbon dioxide, hydrogen sulfide, and water. The cryogenic processes involve separation of gaseous mixtures by fractional condensation and distillation at low temperatures. The disadvantages to this process are: complicated flow schemes, thermal efficiency is low, and capital cost and utility requirements are high.

Existing data indicates that the outlook for energy recovery is optimistic. It appears that there is a sufficient quantity of methane being generated to warrant further investigation of this option. It is recommended that the treatment system be installed as designed. Subsequently, the proper data base could be developed from a field testing program to evaluate the various energy recovery systems. Once the actual system was installed, the following items would be recorded in the data base; extraction rate, methane content, and higher heating value.

Generally, the most economical and profitable alternative is to sell the medium BTU gas to industrial customers if there are no regulatory restraints and/or pricing restrictions. The limiting economic factors are the following items: volume of gas, the landfill location and proximity to customer, local market price, gas use pressure requirements, and compatibility of use when compared to pipeline gas. When a data base regarding the actual system has been established, a market study should be conducted to assess the potential of selling the gas withdrawn from the Combe Fill South.

Given the location of the site it is anticipated that the potential market for selling the gas will be limited. It is therefore likely that the generation of power for use on-site using one of the systems described above will be the most feasible option for use of the landfill gas withdrawn from the Combe Fill South.

SECTION 4 - SHALLOW GROUND WATER RECOVERY SYSTEM

4.01 General

A remedial investigation of the Combe Fill South Landfill site was completed by LMS Engineers in 1986 (Final Remedial Investigation Report: Remedial Investigation/Feasibility Study, Combe Fill South Landfill, May 1986, Lawler, Matusky & Skelly Engineers). As a result of this investigation, response actions which included remediation of ground water at the site were deemed necessary. The Record of Decision (September 1986) identified a shallow ground water recovery system as one of the remedial design components. To aid in the design of this system, O'Brien & Gere Engineers installed four test wells and eight observation wells at select locations around the landfill. These wells were installed so four aquifer performance tests could be conducted to determine the aquifer characteristics of the unconsolidated materials. The addition of eight observation wells allowed an evaluation of the hydraulic characteristics of the saprolite aquifer in different directions and at various distances from the four pumping test wells.

The objectives of designing this shallow ground water recovery system are to collect as much shallow ground water as possible discharging from the landfill and collect this water for on-site treatment, and therefore minimize contact of fill material with ground water. In order to most effectively design a collection system, data obtained from the site were evaluated using several established methods. These included using Darcy's law for determining flow through a given area, Theis' Nonequilibrium equation for determining the potential yield from a shallow recovery well, and Todd's equation to determine radius of inflow to a well. Based on the evaluation of the shallow aquifer data utilizing these methods, a ground water recovery well system of nineteen wells has been designed to collect ground water in the unconsolidated aquifer around the site. In the Spring of 1990, the NJDEP installed two monitoring wells (S-7 and S-8), two exploratory borings (EB-1 and EB-2), and seven test pits (TP-1 through TP-7) in the southeast area of the site. In addition, OBG installed borings BB-1 through BB-7 in this area as part of the geotechnical investigation for the proposed ground water treatment plant. Locations of the NJDEP and OBG wells, borings, and test pits are shown on Figure 4-1.

4.02 Shallow Ground Water Collection Well Design

The Remedial Investigation identified three general groups of unconsolidated materials which constitute the shallow aquifer at the site. The unconsolidated aquifer consists of weathered bedrock material known as saprolite, soil and fill material. The saprolite reportedly has a granitic parent material, and consists of silt, sand, and weathered granite fragments. Soils at the site range from silt to sand, and can generally be described as sandy silt. Thickest deposits of saprolite and soils are seen in the north area of the site near bedrock wells D-1, D-2 and D-5. Based on the Remedial Investigation Report (May 1986), the saprolite and soil deposits range in thickness from 30 to 80 feet. Fill material at the site consists of domestic, municipal, commercial and industrial wastes. Fill material is thickest at the center of the site, near D-6, and appears to thin radially from the center.

Aquifer performance tests were conducted to determine aquifer characteristics such as transmissivity (T) and hydraulic conductivity (K) of the shallow aquifer system. These characteristics are related by the equation K x b = T (where b =

saturated thickness). Once transmissivity is determined, hydraulic conductivity can be calculated since the thickness of the aquifer is known from site test boring data.

4.02.01 Methods

Two approaches were used for the design of the shallow ground water recovery system. The first approach involved the design of the ground water recovery system given the existing ground water flow discharging from the site. The basic goal of this approach was to design a system to prevent shallow ground water from flowing off the site, and to remove and collect as much water as possible from the landfill for on-site treatment. The second approach involved an evaluation of the ground water recovery system with respect to long term site ground water conditions. The goal of this approach was to evaluate the efficiency of the design given the possible significant changes in site ground water flow as a result of the site remediation. In addition, the effectiveness of the remedial design in isolating the fill material from ground water was evaluated.

In order to evaluate the site conditions, available ground water and bedrock elevation data were contoured. Initially, ground water elevation maps were constructed from water level elevations taken on two occasions. Ground water elevations from 8 August 1985 were measured by LMS Engineers as part of the Remedial Investigation. Ground water elevations were also measured on 23 January 1989 by O'Brien & Gere Engineers, Inc. Ground water elevation data for both of these dates are summarized in Table 4-1. Contouring of the water elevations revealed a similar ground water flow

TABLE 4-1

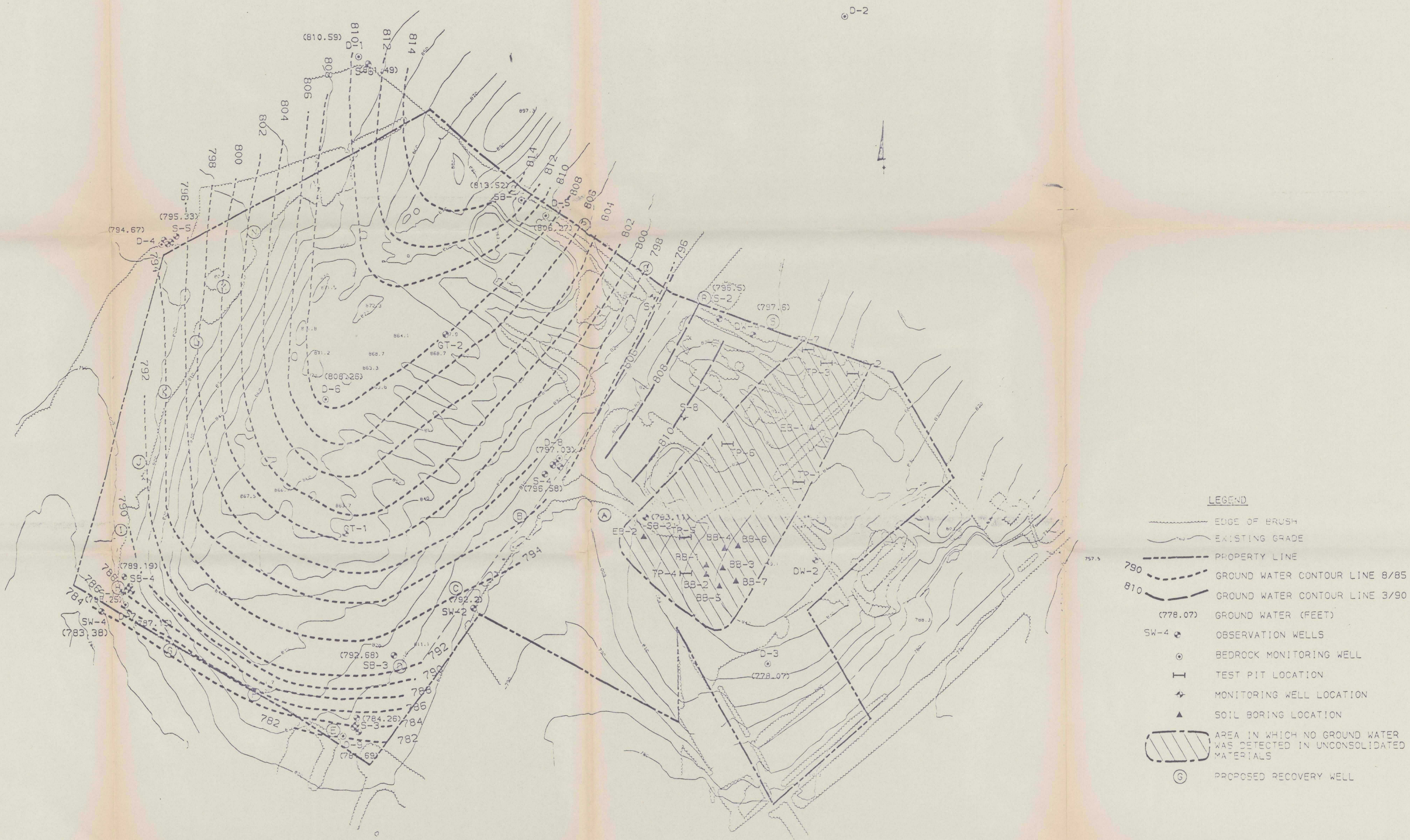
GROUND WATER ELEVATIONS OF 8/28/85 AND 1/23/89

	Ground Water Elevation (ft)	
Well	8/28/85	1/23/89
D-1	810.59	--
D-2	--	--
D-3	778.07	--
D-4	794.67	798.72
D-5	806.27	--
D-6	808.26	808.39
D-7	787.15	788.88
D-8	797.03	801.05
D-9	781.59	784.35
S-1	788.25	790.63
S-2	796.5	800.26
S-3	784.26	787.06
S-4	796.58	800.88
S-5	795.33	800.78
S-6	811.49	817.24
SB-1	813.52	--
SB-2	793.11	--
SB-3	792.68	795.05
SB-4	789.19	792.23
SW-2	792.20	--
SW-4	783.39	--
DW4	797.60	--

configuration on both of these occasions. Ground water elevations from January 23, 1989 averaged approximately four feet higher than elevations collected on August 8, 1985. The final maps represents ground water elevations of August 8, 1985 since ground water elevations on January 23, 1989 were not collected from all of the previously installed wells. In addition, ground water contours in the eastern portion of the site were constructed based on data obtained from the wells, borings and test pits installed by the NJDEP and OBG in the Spring of 1990. While only shallow ground water well elevations were used initially in constructing these maps, the final map incorporated some deep (bedrock) ground water elevations in order to obtain a more complete representation of ground water flow since the only interior well at the site is D-6, which is a deep (bedrock) well. Since similar ground water elevations were observed when comparing adjacent shallow and deep well elevations on several occasions, select deep well elevations were incorporated into the final flow map (Figure 4-1).

Based on the existing ground water elevation data, shallow ground water discharges from the landfill along the entire site perimeter except in areas along the northern and southeastern portions of the site where high bedrock and surface topography results in flow toward the landfill. Through the majority of the site, however, shallow ground water is discharged radially to outlying areas.

In addition to ground water elevation maps, a top of bedrock elevation map was constructed for the site (Figure 4-2). This map is based upon boring logs generated during the Remedial Investigation (LMS 1986) and aquifer



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In charge of ______ Designed by CMG Checked by GAS Made by RCA	1"=200' 200 0 200 400	NO. DATE 11 MAR 1991 INIT.	O'BRIEN & GERE ENGINEERS, INC. Syracuse, New York	COMBE FILL SOUTH LANDFILL SUPERFUND SITE NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

GEOLOGIC
COMBE FILL SOUTH
GROUND WATER CONTOUR MAP

FILE NO. 3013.012-42F
DATE MARCH 1991
4-1

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In charge of			
Designed by CMG	Checked by GAS	1" = 200'	200 0 200 400
Made by RCA			

NO.	DATE	11 MAR 1991	INIT.

O'BRIEN & GERE ENGINEERS, INC.
Syracuse, New York

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF
ENVIRONMENTAL PROTECTION

GEOLOGIC
COMBE FILL SOUTH
BEDROCK ELEVATION MAP

FILE NO. 3013.012-
DATE MARCH 1991

4-2

COMBELF1

LEGEND

EDGE OF BRUSH
EXISTING GRADE
PROPERTY LINE
PROPOSED RECOVERY WELL
BEDROCK MONITORING WELL
SECTION MARKER
OBSERVATION WELLS

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In charge of
Designed by CMG Checked by GAS
Made by RCA

1"=200' 200 0 200 400

NO.	DATE	11 MAR 1991	INIT.

O'BRIEN & GERE ENGINEERS, INC.
Syracuse, New York

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF
ENVIRONMENTAL PROTECTION

GEOLOGIC
COMBE FILL SOUTH
LOCATION OF RECOVERY
WELLS AND SECTIONS

FILE NO. 3013.012-42F
DATE MARCH 1991

4-3

performance tests (OB&G 1988), and subsequent NJDEP and OBG borings and test pits installed in the Spring of 1990.

It should be noted that there appears to be a discrepancy between bedrock elevations obtained from the 1990 boring and test pit installations as compared to elevations obtained from the LMS report. For example, well SB-2 installed as part of LMS investigation and boring EB-2 installed by the NJDEP in 1990 are approximately 80 ft. apart, yet show a bedrock elevation difference of 37 ft. Therefore, the bedrock elevation in SB-2 was not incorporated into this map, but rather the recent NJDEP and OBG data were utilized. There appears to be some difficulty in defining top of bedrock at the Site because of varying degrees of fracturing and/or weathering. The bedrock surface generally dips towards the south at the site. Two mounds are located in the northeast and southeast portions of the site. Saturated thicknesses of the unconsolidated aquifer were determined from the ground water and top of bedrock elevation maps. Saturated thicknesses were approximated from the January 23, 1989 ground water elevation data since higher elevations on this date resulted in higher saturated thicknesses. Thus a worse case scenario could be approximated.

Once collected, these data were evaluated to design an effective shallow ground water recovery system. Aquifer characteristics such as hydraulic conductivity, saturated thickness of the aquifer and ground water flow direction were found to vary across the site. Because of these variations, the site perimeter was segmented into eleven sections to more accurately represent conditions for the system design (Figure 4-3). The sections were established such that each section could be represented by a single hydraulic conductivity (K), saturated thickness (b) and flow direction (Table 4-2). The use of segments in this way more accurately approximates variable site conditions.

Hydraulic conductivity (K) values were based on four pump tests conducted at the site (O'Brien & Gere Memo, 11/3/88). Hydraulic conductivity values were 27, 45, 41 and 71 gpd/ft^2 at wells PT-1, PT-2, PT-3, and PT-4, respectively. The hydraulic conductivity value used in each section was that obtained from the nearest aquifer test, except in the northeast sections I, J and K, where an average value of 46 gpd/ft^2 was assumed. Although an aquifer performance test conducted by LMS Engineers in the area of section K showed an hydraulic conductivity of 15 gpd/ft^2, there does not appear to be any correlation between the other hydraulic conductivity values obtained by LMS and OB&G Engineers for wells in similar locations. The hydraulic conductivity values obtained by O'Brien & Gere Engineers were utilized because the pump tests were of a longer duration and utilized more observation wells around each of the four pump test wells. Data from these tests are thus more accurate than previously determined hydraulic conductivity values from the LMS tests. Hydraulic gradients for each section were calculated within approximately 400 ft of the site perimeter, to more accurately represent the location where the recovery wells will be installed. The hydraulic gradient at the site ranges from 0.016 to 0.025 ft/ft, with an average value of 0.021 ft/ft. Saturated thickness values were determined from the ground water elevation and bedrock elevation maps. In calculating

TABLE 4-2

Combe Fill South Landfill

Section	Recovery Wells	Hydraulic Conductivity (gpd/ft^2)	Gradient (ft/ft)	Length (ft)	Saturated Thickness (ft)	Q = KiA (gpd)	Theis Well Yield (gpd)	Theis Well Yield (gpm)	Todd Radius of Inflow (ft)	Number of Wells Needed
A	M,N	71	.02	480	29	19766	23615	16.4	287	2
B	K,L	71	.02	660	30	28116	25245	17.5	296	2
C	I,J	41	.02	650	30	15990	15155	10.5	308	2
D	G,H	41	.018	475	25	8764	10650	7.4	289	2
E	F	41	.02	440	30	10824	15155	10.5	308	1
F	E	45	.02	400	29	10440	15445	10.7	296	1
G	D	45	.016	480	34	11750	20910	14.5	427	1
H	A,B,C	27	.018	950	39	18006	17015	11.8	449	3
I	O,P	46	.025	560	29	18676	15830	11.0	237	2
J	Q	46	.024	280	42	12983	32205	22.4	347	1
K	R,S	46	.021	475	38	17436	26505	18.4	361	2
						172,751				

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saturated thicknesses, ground water elevations of January 23, 1989 were utilized as these elevations were generally four feet higher than the August 28, 1985 elevations. Thus, high water levels at the site were approximated to obtain a maximum discharge for the site. The saturated thickness of the aquifer ranges from 25 to 42 ft, with an average value of 32 ft. Aquifer values utilized in each of the eleven sections are presented in Table 4-2.

Along the northwest perimeter of the site, Section A is adjacent to a northern recharge area. Since this section is closest to well PT-4, the hydraulic conductivity value observed at that well, 71 gpd/ft^2, was used in calculations for this section. The hydraulic gradient estimated in this section was approximately 0.02 ft/ft. High saturated thicknesses are observed along this side of the landfill, with an average value of 29 ft in Section A.

The western perimeter of the landfill was divided into Sections B and C. Pump tests at the north and south ends of this side showed hydraulic conductivity values of 71 and 41 gpd/ft^2 respectively. Thus for calculations in Section B, an hydraulic conductivity value of 71 gpd/ft^2 was used while an hydraulic conductivity value of 41 gpd/ft^2 was used in Section C. Saturated thicknesses of the saprolite aquifer averaged 30 ft in both Sections B and C. An hydraulic gradient of 0.02 ft/ft was estimated in both of these sections.

The southwest face of the landfill was divided into Sections D, E and F. Hydraulic conductivity values used were 41 gpd/ft^2 in sections D and E, and 45 gpd/ft^2 in section F. Hydraulic gradients were 0.018 ft/ft in section D, and 0.02 ft/ft in sections E and F. The saturated thickness of the aquifer was 25 ft in section D, 30 ft in section E, and 29 ft in section F.

The segmentation of the southeast face of the landfill is based primarily on saturated thickness of the aquifer. The hydraulic conductivity value for the well near section G (PT-2) is 45 gpd/ft^2, while a value of 27 gpd/ft^2 was used in section H because of its proximity to well PT-1. The hydraulic gradients are 0.016 ft/ft and 0.018 ft/ft in sections G and H, respectively. The saturated thickness of the aquifer in section G averages 34 ft. Along Section H, the saturated materials average 39 ft thick.

Between sections H in the southeast and section K in the northeast is an area where no section was established. To the southeast of section H, a topographic and bedrock high is present. Based on this topographic bedrock high and the fact that ground water flow generally follows topography, ground water will not discharge to the southeast past this bedrock high. Rather ground water flow from this area is toward the main landfill.

Along the northeast side of the landfill, an inflow area in the north, as well as Sections I and J were established. Because no hydraulic conductivity values were obtained in this area, the site average value of 46 gpd/ft^2 was used in calculations. Hydraulic gradients are approximately 0.025 ft/ft and 0.024 ft/ft and saturated thicknesses are 29 and 42 ft in sections I and J, respectively. Section K is the only section along the eastern side of the landfill. An hydraulic conductivity value of 46 gpd/ft^2, an approximate hydraulic gradient of 0.021 ft/ft, and aquifer saturated thickness of 38 ft were utilized for this section.

Once the site was divided into sections, the approximate volume of ground water flow through each section was calculated. For each section, Darcy's Law (Q=KiA, where Q=discharge in gallons per day (gpd); K=hydraulic conductivity in gpd/ft^2; i=hydraulic gradient in ft/ft; and A=cross-sectional area in ft^2) was used to calculate an approximate discharge. Values utilized in each of the sections are shown on Table 4-2 in the columns labelled hydraulic conductivity, gradient, length, and saturated thickness (note: length times saturated thickness equals cross-sectional area). Discharge from each of the eleven sections is shown in the column labelled Q=KiA.

The total shallow ground water discharge for the site is estimated at 173,000 gallons/day (Table 4-2). LMS Engineers (LMS 1986) calculated an approximate volume of 122,000 gpd in the Remedial Investigation (LMS, 1986). Our value is 40% higher, and is the result of greater detail associated with the division into eleven sections as well as high hydraulic conductivities and higher saturated thicknesses associated with water levels being an average four feet higher on January 23, 1989 vs. the elevations of August 8, 1985.

Similar calculations were performed for the north shallow ground water inflow area. In the north inflow area, an average gradient of 0.015 ft/ft, hydraulic conductivity of 46 gpd/ft^2 and saturated thickness of 40 ft along a length of 975 ft resulted in an estimated shallow ground water inflow of approximately 27,000 gallons/day. LMS Engineers calculated an inflow of 6,250 gpd by applying the calculated annual recharge rate for the landfill area (1,250 gpd/acre) to the 5-acre upgradient recharge area (Final Conceptual Design Report, June 1987).

Once a volume of ground water flowing out of each section was determined, it was necessary to calculate the volume of ground water a typical shallow recovery well in that section could produce. Once a typical well yield was known, then the number of wells needed to collect the total section discharge could be determined.

Theis' nonequilibrium equation was used to determine the well yield for a typical well in each section. The Theis solution is a mathematical expression for describing the relation between well yield, drawdown (s), transmissivity (T), and storativity (S). Theis related the aquifer properties transmissivity and storativity, and the pumping rate (Q) to drawdown in a well, by the following equations:

$$u = \frac{1.87\, r^2 S}{Tt} \quad (1)$$

$$Q = \frac{Ts}{114.6\, W(u)} \quad (2)$$

where r=distance in ft from center of pumped well to a point where drawdown is measured; S=coefficient of storage (dimensionless); T=transmissivity in gpd/ft; t=time since pumping started; Q=well yield in gallons per minute (gpm); s=drawdown in ft; and W(u)=well function.

Transmissivity values (T=hydraulic conductivity x aquifer thickness) across the site ranged from 1025 to 2130 gpd/ft, with an average value of 1507 gpd/ft. The storage coefficient of the aquifer is approximately 0.3, based on typical values in the literature for the materials encountered during drilling (Davis & DeWiest, 1966). These materials include silty clay, silty sand, sandy silt and sand. Once u was determined from equation 1, the corresponding value of W(u) was obtained from the tabulated values of u and W(u). Well yield was then determined by use of Equation 2. Calculations utilizing the Theis equation are included as Appendix 4-1.

Recovery well drawdown values used were assumed to be 75% of the saturated thicknesses, resulting in a conservative estimate. This selected drawdown is conservative in that drawdown can be in excess of 75% of the saturated thickness. Therefore, well yield can be increased by increasing the drawdown. Unconfined drawdown values were converted to confined equivalents for use in the Theis solution. Well yields calculated using the Theis method are shown on Table 4-2 in the columns labelled "Theis Well Yield (gpd)" and "Theis Well Yield (gpm)". Well yields for typical recovery wells ranged from 10,650 to 32,205 gallons/day or 7.4 to 22.4 gpm (Table 4-2). By dividing the estimated well yields into the calculated discharge from each section, the number of recovery wells required for each section was calculated. As evidenced on Table 4-2, there are cases where a partial well would be needed to pump the estimated outflow in a section. In such cases, the number of wells needed was rounded off to the next higher whole number. This would allow the wells to be pumped at a lower capacity while still collecting ground water in that section. Similarly, if the estimated outflow calculated for a given section was similar to the well yield for a typical well in that section, an additional well was added to account for possible variability in the aquifer coefficients.

To further evaluate the number of shallow recovery wells required, the radius of inflow for a typical well in each section was calculated using the Todd equation:

$$y = Q/2\ Kbi$$

(D.K. Todd, 1980) where y=radius in ft; Q=well yield in gallons/day; K=hydraulic conductivity in gpd/ft^2; b=saturated thickness in ft; and i=hydraulic gradient in ft/ft. The radius of inflow is the radius perpendicular to the direction of ground water flow from which ground water will flow to the recovery well. Values for the radius of inflow obtained for wells at the site are shown on Table 4-2 in the column labelled "Todd Radius of Inflow". These values ranged from 251 to 449 ft, as shown in Table 4-2. Since the length of a given section is known, it can be determined if the radius of inflow is sufficient to capture all of the ground water along that length. If the length of a given section was similar to or greater than the diameter of inflow, more than one well would be necessary. The final number and spacing of wells was based on analysis of all calculations. Figure 4-3 shows the shallow ground water recovery system configuration. An additional well was proposed in Section H to collect additional ground water which may be added due to the proximity to the southeast inflow area. Also, an additional well was placed in Section K because no data were available to the east of this location.

Similar calculations were completed for the Final Conceptual Design Report by LMS Engineers. LMS employed the Theis equation to estimated the radius of inflow, assuming a radius where a drawdown of one or two feet occurred to represent the maximum radius of inflow. Calculations were completed assuming average conditions across the site, and did not account for any variations across the site. An average radius of inflow was calculated as 100 ft, but a 50 ft radius was assumed for determining the number of recovery wells. This assumption was reportedly incorporated to ensure that there were enough wells if variations in the subsurface hydrogeology did occur. Using a drawdown of one or two feet as a basis for identifying a radius of inflow is conservative in itself, and a 100 ft radius should be effective for the recovery well system design. Thus LMS Engineers was overly conservative in their proposed recovery system design.

4.02.02 System Design

The alignment of the shallow ground water recovery system is along the perimeter of the landfill cap. The estimated total number of recovery wells in the shallow ground water recovery system is nineteen. These recovery wells have been located around the shallow ground water discharge areas of the site. The number of wells proposed in each section can be seen in Figure 4-3 and Table 4-2. The proposed spacing of the wells is also shown on Figure 4-3. It should be noted that the proposed well locations are approximate. Exact placement of the wells may vary somewhat depending upon geologic conditions in a given section as well and the final design of the other site remedial features. Hydrogeologic factors which may affect the location and spacing of wells include local bedrock topography, overburden characteristics, and access obstructions. If local bedrock topography includes a mound such that a well is in a location where only water from one side of the mound could be effectively collected, the well location may be modified and/or the number of wells may be modified. Overburden conditions such as an abnormally permeable unit could be another reason to change well locations.

4.02.03 Long Term Effects

In designing the ground water recovery system, an evaluation of the remedial design with respect to long term conditions was completed. This evaluation was performed to evaluate the long term efficiency of the shallow ground water recovery system and also to evaluate the ability of the site remediation to isolate the fill material from ground water by lowering the water table. In order to evaluate the proposed system, it was necessary to address inflow and outflow at the site over time. Initially the unconsolidated aquifer would discharge a volume of ground water through the eleven sections as calculated using Darcy's law, 173,000 gpd. Once the proposed cap was placed over a majority of the landfill, inflow would be reduced and limited to the north recharge area as well as infiltration through the cap. With this reduced inflow, the volume of water discharging from the site and collected by the shallow ground water recovery system would also be reduced. Eventually an equilibrium condition would be approached where the volume of inflow and the volume of shallow ground water discharging from the site would be balanced, and the ground water elevation in the landfill would be stabilized.

In order to evaluate the recovery well system with respect to long term site ground water conditions, a site ground water budget was calculated. The total ground water inflow minus outflow equals the change in ground water storage within the site. Site equilibrium occurs when the volume of water inflowing to the site is equal to outflow from the site to the shallow ground water recovery system. For the Combe South landfill, inflow to the site is provided through the north inflow area as well as infiltration through the cap. Utilizing cap system F, infiltration through the cap was estimated to range from an average daily percolation of 3715 to 26,495 gpd into the waste layer. While the infiltration rate remains constant, inflow and outflow calculations utilizing Darcy's law are dependent on the hydraulic gradient. Thus to represent site equilibrium conditions, it was necessary to balance inflow and outflow by varying the hydraulic gradient. Calculations were performed for both the low cap inflow value of 3715 gpd and a higher value of 26,495 gpd. By calculating inflow and outflow at various gradients through a series of calculations, it was determined that a gradient which is approximately 3% of the present gradient resulted in a ground water balance budget for the site when infiltration is 3715 gpd, while a ground water balance budget is reached at approximately 20% of the present slope when infiltration through the cap is 26,495 gpd (Appendix 4-2). The water level over time associated with these reduced gradient results in estimated reduction in the water level in the center of the site of approximately 16.5 and 14 ft respectively for infiltration values of 3715 and 26,495 gpd. This would result in estimated projected water levels in the center of the site of approximately 792 ft and 794 ft respectively for infiltration rates of 3715 and 26,495 gpd.

These calculations suggest that with time, the hydraulic gradient at the site will be much less steep than its present configuration. The lowered water table will isolate much of the fill material from ground water contact, thereby reducing the volume of ground water being impacted by the fill. With inflow thus limited, it may be possible to reduce the pumping rate of the wells, and/or possibly utilize only some of the recovery wells to effectively capture the ground water.

Figure A1 and A2 in Appendix 4-2, representing ground water discharge calculations through time for cap percolation rates of 3715 and 26,495 gpd respectively, were generated using Darcy flow calculations for approximate ground water flow through the sections.

These calculations are based on the total volume of ground water discharging from the eleven sections. Once an estimated volume of ground water is removed from the landfill by pumping, the gradient at the site will change and a lower discharge will occur. This scenario will continue until site equilibrium is attained. Depending upon the actual pumping rates of the recovery wells, the time it takes for equilibrium to be attained may vary from the values predicted in these figures.

Figure A1 shows that with a cap percolation rate od 3715 gpd, 124,000 gpd is the Darcy flow discharge after one year. After two years, discharge decreases to 90,000 gpd, or approximately a 50% decrease in two years. Figure A2 shows that using a percolation rate of 26,495 gpd, discharge after one year is 133,000 gpd and decreases to 104,000 gpd in two years, approximately a 40% decrease.

Although these values represent approximate flow at the site, maximum discharge from the site can be approximated by utilizing Theis' calculations for maximum well yields from typical recovery wells. In most cases, one well could theoretically collect the ground water estimated to be flowing through the section. In sections B and I, the estimated discharge is more than 10% greater than the theoretical well yield, and thus two wells were utilized for the maximum discharge calculation. This results in a maximum discharge of 260,000 gpd. This value is approximately 50% greater than the maximum Darcy flow determination. The Darcy flow volume probably represents a more realistic discharge value.

However, pumping the recovery wells at or near their maximum discharge will result in development of the cones of influence as determined in the Todd calculations. This will result in attaining site equilibrium within approximately six months to one year.

Utilizing the fact that the total maximum discharge value of 260,000 gpd is 50% greater than the total Darcy flow discharge, the Darcy flow discharge through time calculations can be corrected to predict maximum discharge through time. Figures A3 and A4 show maximum discharge through time for percolation rates of 3715 and 26,495 gpd respectively. With a cap percolation rate of 3715 gpd, 187,000 gpd is the maximum discharge after one year. After two years, discharge decreases to 135,000 gpd, or approximately a 50% decrease in two years. Similarly, using a percolation rate of 26,495 gpd, discharge after one year is 200,000 gpd and decreases to 155,000 gpd in two years, a 40% decrease. Because of this rapid decrease in ground water discharge that initially occurs, and the fact that the cap will most likely be in place for at least one year before the recovery well system begins operation, the ground water treatment facility was designed to collect a total volume of 145,000 gpd.

4.02.04 Recovery Well Design

In designing the recovery wells, several components were evaluated to produce the most efficient design. These components include construction materials, well diameter, boring diameter, screen slot size, screen length, filter pack design, and pump size.

Recovery wells at the Combe site will be constructed of 6-inch I.D. stainless steel screen and riser. A 4-inch I.D. well screen would not allow enough clearance for most submersible pumps, thus a 6-inch I.D. well screen is recommended. Stainless steel is recommended because of the possible corrosive nature of ground water associated with fill material. Stainless steel provides excellent corrosion resistance and is thus the most durable construction material. (Groundwater and Wells, 1986). Although stainless steel is subject to corrosion by chlorides, interim environmental monitoring data show relatively low chloride concentrations, with a high value of 1017 mg/l. In addition, because the system will be operating for an extended period of time, stainless steel is preferable. The proposed recovery wells will be installed in 12-inch borings. To ensure that a continuous layer of filter material surrounds the well screen, the annulus around the well screen be at least three inches. Thus, with a six inch well, a 12-inch boring is proposed (Groundwater and Wells, 1986).

In determining a suitable filter pack and screen slot size, five available grain size analyses from borings at the site were analyzed. These analyses were conducted by Borings, Soils, and Testing Co. (6/85) on samples obtained from SB-2 (18 to 20 ft and 26 to 28 ft), SB-3 (24 to 28 ft) and SB-4 (6 to 8 ft and 6 to 18 ft). Using methods described in Groundwater and Wells (1986), the filter pack and screen slot size were determined. To determine a suitable filter pack, the 70 percent retained size from the grain size curve was multiplied by a factor of 6. Through this point, a smooth curve is drawn which has a uniformity coefficient of 2.5 or less. This curve represents a suitable filter pack material for the well. The curves drawn for the five grain size analyses were similar to the grain size curve for the commercially available filter pack Morie sand #00. The material used for the filter pack should meet these specifications for the commercially available Morie #00 or an equivalent filter pack:

Grain Size	Percent Retained
0.3 mm	100%
0.6 mm	50%
0.65 mm	30%
0.75 mm	10%

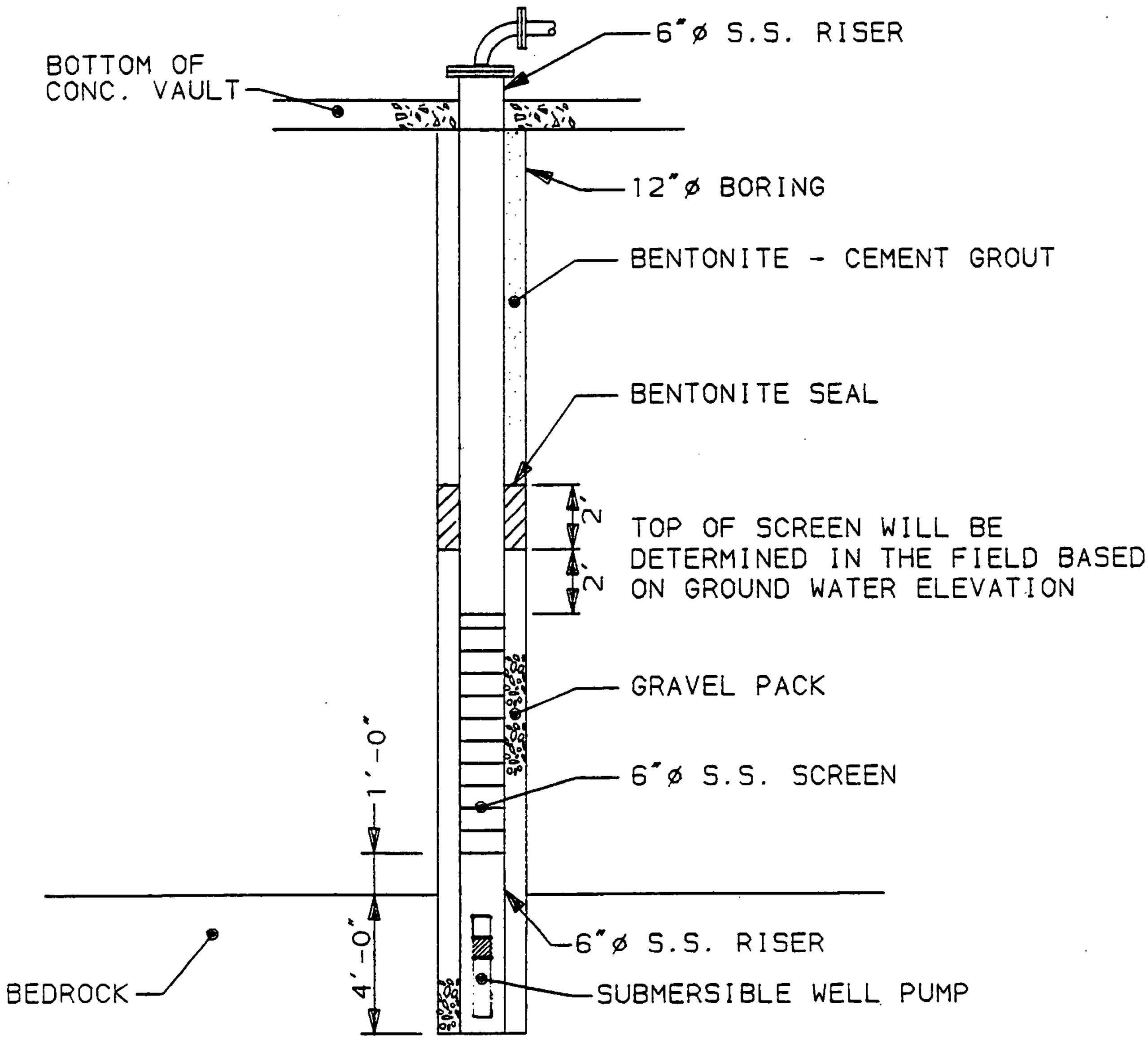
A suitable screen slot size should retain 90 percent or more of the filter pack material. Since the 90 percent retained grain size for Morie #00 is 0.012 inch, a 0.010 inch screen slot size is appropriate for the recovery wells.

The saprolite aquifer will be screened through its entire saturated thickness, resulting in an average screen length of approximately 25 ft. Due to the non-homogenous nature of the fill material, it may be easier for ground water to flow horizontally towards the screen than to induce vertical flow to a partially penetrating well. Screening most of the aquifer would thus enhance ground water recovery. Figure 4-4 is a schematic for a typical shallow ground water recovery well at the Combe Fill South site.

4.03 Shallow Ground Water Collection and Conveyance System

Ground water within the Combe Fill South Landfill, will be collected by a Shallow Ground Water Collection and Conveyance System. This system will consist of nineteen (19) wells with submersible pumps. The pump controls and valving will be located in a concrete vault, above each well. The ground water collected in the wells will be pumped to two separate forcemain headers which will discharge at the top of the treatment plant equalization tank at the treatment plant.

FIGURE 4-4



RECOVERY WELL DETAIL

NOT TO SCALE

4.03.01 Parameters

The design of the system was dependent upon a number of natural and imposed parameters. Due to the higher elevation in the northwest corner of the landfill, the system has been designed with two forcemain headers flowing in opposite directions, away from the hill, towards the treatment plant. The headers will not be installed under any fill areas or within any wetland areas. Although the headers will be permitted to cross the power company right-of-way, headers parallel to and contained within the right-of-way will not be permitted.

The recovery wells located around the perimeter of the landfill are labelled A through S clockwise. The approximate design flow rate for each well is listed in Table 4-3. The drawdown depth in each well is specified to be no less than one (1) foot above the bedrock elevation. Calculations of the header diameter and individual well pump sizes are included in Appendix 4-3.

The forcemain headers will be six- and eight-inch diameter HDPE pipe, based on its compatibility with the ground water. Stainless steel pipe has been specified for the riser section and valving in each well due to its strength and also its compatibility with the ground water. The design flow rate and dynamic head for each well are shown in Appendix 4-3. The pump bodies will be stainless steel with Teflon seals.

TABLE 4-3

Shallow Ground Water Recovery System Well Flow Rates

COMBE FILL SOUTH LANDFILL REMEDIAL CONSTRUCTION

Well Identification	Design Flow Rate In Gallons Per Minute (GPM)
A	12
B	13
C	13
D	18
E	11
F	10.5
G	10.5
H	11
I	11
J	12
K	17.5
L	19
M	20
N	22
O	12
P	13
Q	29
R	29
S	20

4.03.02 Well Operation

Each well will be cased in a gravel pack and sealed with bentonite clay. The submersible pumps will be controlled by level sensors which will be installed with a high and low level switch, with a redundant shutoff, and an interlock to shutdown at high level in T101. The level sensor will sense the pump shut-off depth and will consequently shut off the submersible pump. Once the well recharges to the preset level, the level sensor will reactivate the pump.

The pump motors will be kept submerged under a minimum two (2) feet of ground water with intrinsically safe level controls and a redundant shut off, all to help prevent explosion. The pump system shall also include a field programmable "interval on" timer for each ground water recovery well along with a flow indicator/totalizer. These devices will allow operational control flexibility to extract ground water from more highly contaminated areas.

SECTION 5 - GROUND WATER TREATMENT SYSTEM

5.01 General

The Combe Fill South Landfill in Chester and Washington Townships, Morris County, New Jersey, has accepted municipal and industrial wastes since the 1940s. This inactive landfill consists of three separate disposal areas covering about sixty-five acres. Approximately five million cubic yards of waste material were buried within the Combe Fill South Landfill. The majority of the waste includes typical household waste and non-hazardous industrial waste. However, the presence of volatile organic compounds has been identified beneath the site within two ground water aquifers (shallow and deep). Some of these volatile organic compounds have been detected in samples collected from nearby potable residential wells.

The Combe Fill South Landfill site was listed on the National Priority List in September 1983. Subsequently, a Remedial Investigation/Feasibility Study (RI/FS) was conducted from 1984 through 1985 under the lead of the New Jersey Department of Environmental Protection (NJDEP). The Record of Decision (ROD) for this site has identified the following areas to be encompassed within the Remedial Design:

1. An active collection and treatment system for methane and any other landfill generated gases.
2. Expanded environmental monitoring of water, air, soils and leachate.
3. A multi-layered cap that covers the landfilled areas and extends under the utility company right-of-way.

4. Pumping and on-site treatment of shallow ground water with discharge to Trout Brook.

5. Surface water controls to accommodate runoff from both normal precipitation and severe storms.

6. Security fencing, an access road and general site preparation.

Separate sections of this report present the design of the cover system, the shallow ground water collection and conveyance system, and the landfill gas system. This section provides results of ground water treatability testing, as well as the basis of design of the on-site ground water treatment facility.

5.02 Ground Water Characteristics and Treatability Testing

5.02.01 Background

As previously stated, the ROD for the Combe Fill South Landfill (CFSL) identified a selected remedy, which among other items, includes the following components:

- An active collection and treatment system for landfill gases; and
- Pumping and on-site treatment of shallow ground water with discharge to Trout Brook.

Ground water will be collected by a series of ground water recovery wells. This recovered ground water will initially contain a component of "leachate", or water which has been directly exposed to landfilled materials. As the landfill installation proceeds to completion, and precipitation infiltration through the landfilled materials declines, the recovered ground water will decline in strength and volume.

The landfill gas collection and treatment system will generate a liquid waste stream formed by condensation of gas vapors. This condensate will be formed as a result of temperature differences between landfill gas and ambient air. The nature of condensate is such that treatment is required prior to discharge to receiving waters. Condensate generation and treatment at the site was not identified by the RI/FS report or in the ROD, nor was it anticipated in the ongoing remedial design RFP or contract. Landfill gas condensate has only recently been identified as an issue at the site.

This section identifies known and estimated characteristics of ground water, and landfill gas condensate. This section addresses treatability testing conducted on shallow aquifer ground water only. Landfill gas condensate treatability testing was not conducted, as the volume of landfill gas condensate produced from a small scale gas withdrawal test was insufficient to conduct reasonably scaled biological treatability studies (one liter of feed per day or greater). Treatment system components required to meet discharge requirements are recommended herein.

5.02.02 Objectives

The principal objective of the ground water treatability study was to provide a conceptual design for a system to treat ground water from the shallow aquifer beneath the Combe Fill South Landfill. The specific objectives of the ground water treatability study were to evaluate the efficiency and efficacy of:

1) chemical precipitation and subsequent settling of metals,

2) biological treatment of organics,

3) mixed media filtration for the removal of solids, and

4) air stripping and activated carbon polishing for removal of organics resistant to biological treatment.

Four unit operations sequences were evaluated in the treatability study (Figure 5-1).

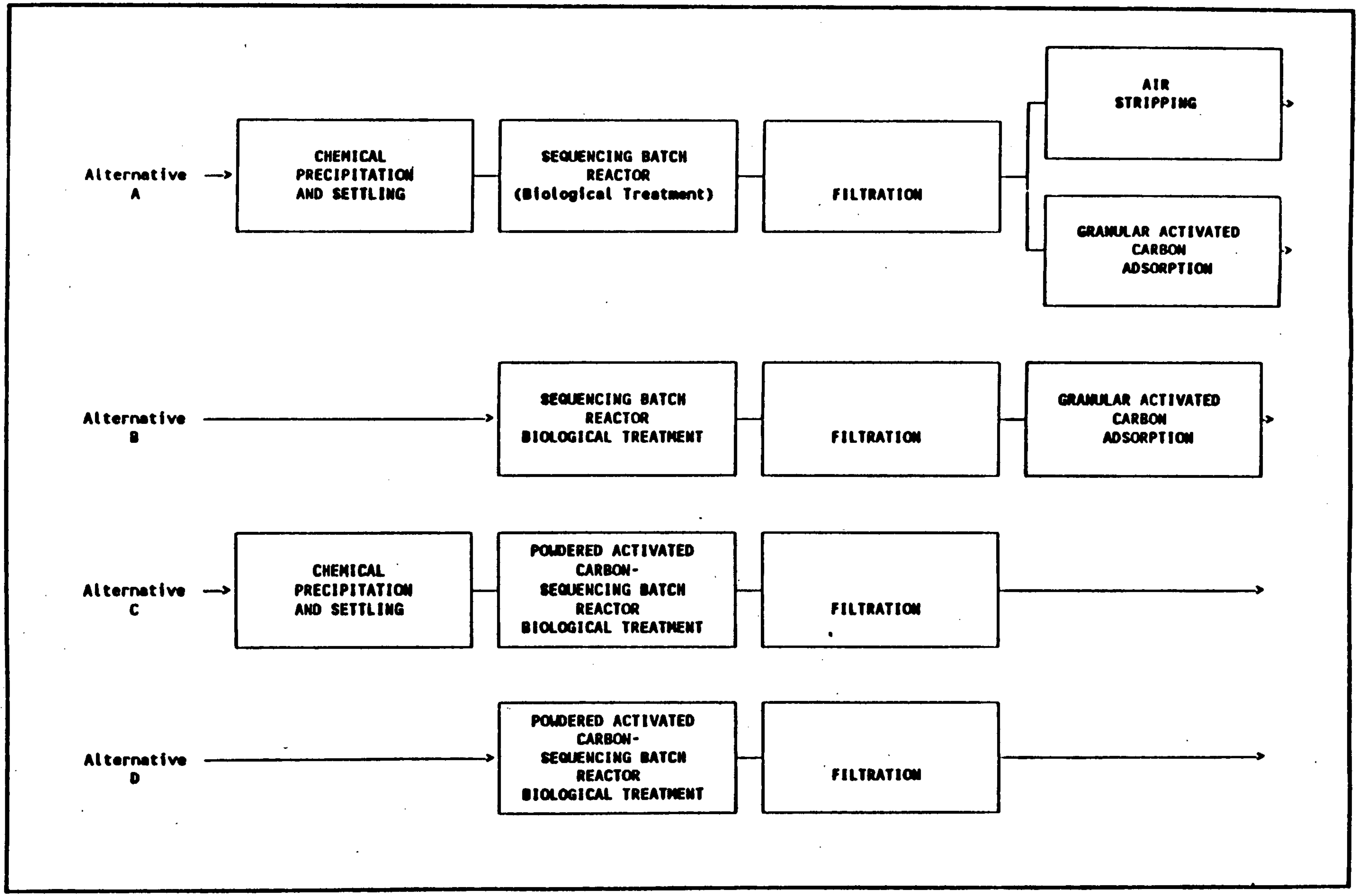
5.02.03 Ground Water and Condensate Characteristics

The Remedial Investigation (RI) assessed the nature of ground water contamination at the site from data collected from six shallow wells within the fill area and leachate collected from eight seeps surrounding the fill area. Table 5-1 contains ranges and mean concentrations of organic and inorganic substances contained in the ground water as reported in the RI report. Table 5-2 contains the effluent limitations for the treatment facility as proposed by NJDEP along with the expected average influent characteristics to the proposed ground water treatment facility, as presented in the Final Conceptual Design Report [1]. These data indicate the following:

- Ground water five-day biochemical oxygen demand (BOD5) is low (approximately 100 mg/L) for a self-sustaining biological treatment system.
- Ground water total suspended solids concentration (TSS) is relatively high (about 480 mg/L).

Figure 5 -1
Combe Fill South Landfill
Ground Water Treatability Study

Alternative Process Schematics for Ground Water Treatment



Combe Fill South Landfill
Ground Water Treatability Study

Table 5-1

Ground Water and Leachate Characteristics - Remedial Investigation (1986)

PARAMETER	SHALLOW GROUND WATER MINIMUM	SHALLOW GROUND WATER MAXIMUM	SHALLOW GROUND WATER PREDESIGN	LEACHATE COMPOSITE MINIMUM	LEACHATE COMPOSITE MAXIMUM	LEACHATE COMPOSITE PREDESIGN
VOLATILES (ppb)				15.0	1084.0	261.7
Benzene	0.0	80.2	26.4			
Chlorobenzene	0.0	30.3	11.6			
Chloroethane	0.0	62.0	12.0			
Chloroform	0.0	57.5	9.6			
1,1-Dichloroethane	0.0	65.2	20.2			
1,2-Dichloroethane	0.0	6.1	1.0			
1,1-Dichloroethylene	0.0	0.0	0.0			
1,2-Dichloropropane	0.0	6.0	1.0			
Ethylbenzene	0.0	7.2	1.2			
Methylene chloride	4.44	56.0	16.1			
Tetrachloroethylene	0.0	4.1	0.7			
Toluene	0.0	1370.0	239.7			
Trans-1,2-dichoroethylene	0.0	8.0	1.3			
Trichloroethylene	0.0	4.0	0.7			
Vinyl Chloride	0.0	10.0	1.7			
ACID/PHENOLICS (ppb)				0.0	7.0	1.8
2,4-Dimethylphenol	0.0	0.0	0.0			
2-Nitrophenol	0.0	0.0	0.0			
Phenol	0.0	1.5	0.3			
BASE/NEUTRALS (ppb)				2.0	71.0	34.5
Bis(2-chloroethyl)ether	0.0	5.8	1.8			
Bis(2-ethylhexyl)phthalate	0.0	11.0	3.5			
1,2-Dichlorobenzene	0.0	9.77	2.8			
1,4-Dichlorobenzene	0.0	39.4	8.3			

Combe Fill South Landfill
Ground Water Treatability Study

Ground Water and Leachate Characteristics - Remedial Investigation (1986)

PARAMETER	SHALLOW GROUND WATER MINIMUM	SHALLOW GROUND WATER MAXIMUM	SHALLOW GROUND WATER PREDESIGN	LEACHATE COMPOSITE MINIMUM	LEACHATE COMPOSITE MAXIMUM	LEACHATE COMPOSITE PREDESIGN
BASE/NEUTRALS (ppb) Cont'd.				2.0	71.0	34.5
Di-ethyl phthalate	0.0	10.2	1.7			
Di-n-butyl phthalate	0.0	11.0	3.5			
Di-n-octyl phthalate	0.0	0.0	0.0			
Isophorone	0.0	0.0	0.0			
Naphthalene	0.0	3.2	0.5			
N-nitrosodiphenyl amine	0.0	0.0	0.0			
PESTICIDES/PCBs (ppb)				0.0	0.0	0.0
METAL (ppb)				60.0	3180.0	700.0
Beryllium	0.0	2.0	0.3			
Cadmium	0.0	3.0	0.5			
Chromium	0.0	30.0	13.3			
Copper	10.0	40.0	20.0			
Lead	9.0	28.0	16.7			
Mercury	0.0	0.2	0.1			
Nickel	0.0	30.0	11.5			
Selenium	0.0	5.0	0.8			
Silver	0.0	10.0	4.8			
Thallium	0.0	5.0	1.7			
Zinc	0.0	240.0	78.3			
MISCELLANEOUS (ppb)						
Cyanides	0.0	0.0	0.0	0.0	47.0	24.0
Phenols	0.0	270.0	45.0	0.0	418.0	212.7

TABLE 5 - 2

Combe Fill South Landfill
Ground Water Treatability Study

Ground Water Influent Characteristics and Effluent Limits - Conceptual Design Report (1987)

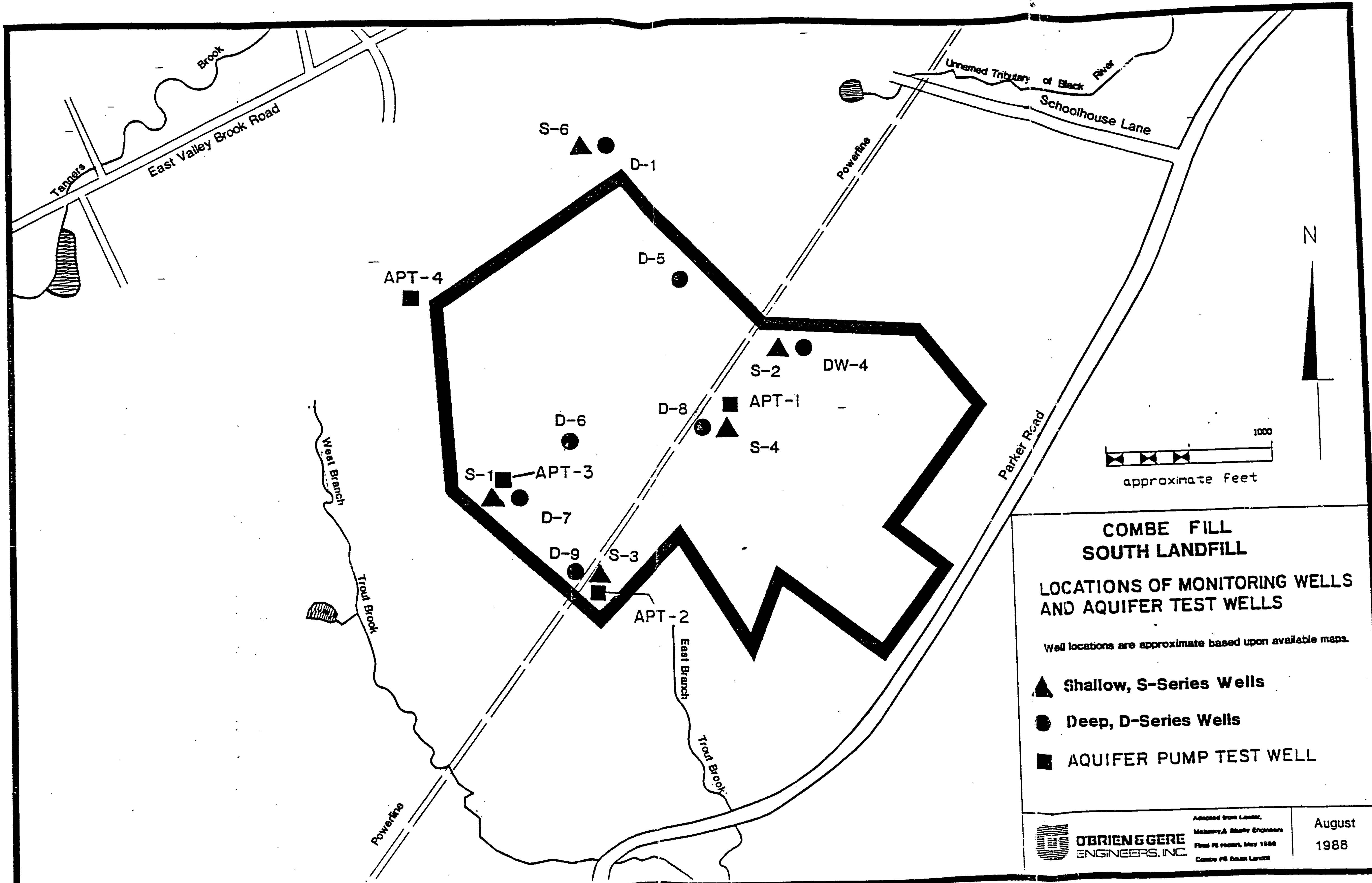
COMPONENT	EFFLUENT LIMITATIONS	EXPECTED AVERAGE INFLUENT CHARACTERISTICS
Conventional Parameters		
Biochemical oxygen demand, 5 day (BOD_5)	8.0 mg/l monthly average 12.0 mg/l weekly average 20.0 mg/l daily maximum 90% removal efficiency	100 mg/l
Total suspended solids (TSS)	8.0 mg/l monthly average 12.0 mg/l weekly average 20.0 mg/l daily maximum 85% removal efficiency	480 mg/l
Total organic carbon. (TOC)	10.0 mg/l monthly average 20.0 mg/l daily maximum	510 mg/l
pH	6.5 - 8.5	7.0
Dissolved oxygen (DO)	7.0 mg/l at any time	-
Ammonia, as nitrogen (NH_3-N)	1.0 mg/l monthly average[a]	50 mg/l
Bioassay	No measurable acute toxicity	-
	96-hr LC_{50} < 10% mortality in all samples, including 100% treatment effluent	-
Ames Test	(No numerical limit for mutagenicity)	-
Priority Pollutants		
Volatile and semivolatile organics (NJDEP "toxic" organics)	ND or <5 ppb, for any single compound, daily maximum	300 ppb
Polychlorinated biphenyls (PCBs)	ND or <0.1 ppb, daily maximum	ND
Pesticides	ND or <1.0 ppb, daily maximum	ND
Heavy metals	ND or <50 ppb, total for all metals, daily maximum	710 ppb
Total phenolics	ND or <50 ppb, daily maximum	210 ppb
Total cyanide	ND or <20 ppb, daily maximum	24 ppb

[a]Possible allowances for seasonal variations not quantified.

ND = not detectable.

- Relative to BOD5, ground water total organic carbon (TOC) is high (510 mg/L), suggesting the presence of biologically inert or refractory organic materials.
- Volatile organic substances are present in ground water at concentrations typically removed by biological treatment facilities (less than 10 to 100 ug/L).
- Neither pesticides nor PCBs were detected in ground water or leachate.
- Ground water heavy metal concentrations are consistently within the range compatible with biological treatment systems (less than 10 to 250 ug/L).
- Ground water concentrations of cyanides and phenols (24 and 210 ug/L, respectively) should be able to be treated with application of biological treatment systems without requiring pretreatment for these substances.

Ground water characterization was conducted under the scope of the remedial design treatability testing program. Samples of ground water were collected from four aquifer pump test (APT) wells both 24 hours and 48 hours after commencement of each pump test. Figure 5-2, a plan view of the site, depicts the location of the APT wells in addition to ground water monitoring wells. The purpose of the ground water characterization effort was to determine the quality of ground water from the shallow aquifer under pumping conditions similar to those expected during future active ground water recovery and treatment.


Brook
East Valley Brook Road
Tanners
Unnamed Tributary of Black River
Schoolhouse Lane
Powerline
Parker Road
West Branch
Trout Brook
East Branch
Trout Brook
Powerline
N
1000
approximate feet
S-6
D-1
D-5
APT-4
S-2
DW-4
APT-1
D-8
S-4
D-6
S-1
APT-3
D-7
D-9
S-3
APT-2
COMBE FILL
SOUTH LANDFILL
LOCATIONS OF MONITORING WELLS
AND AQUIFER TEST WELLS
Well locations are approximate based upon available maps.
Shallow, S-Series Wells
Deep, D-Series Wells
AQUIFER PUMP TEST WELL
O'BRIEN & GERE ENGINEERS, INC.
August
1988

An aliquot of each sample was filtered in the field to provide a basis for determining the distribution of metals and Total Organic Carbon (TOC) between the particulate and aqueous phase of the ground water. Additionally, the eight APT samples were analyzed for total phenolics, volatile organics (Environmental Protection Agency (EPA) Methods 601 and 602), total metals (beryllium, cadmium, calcium, copper, chromium, iron, lead, magnesium, nickel, selenium, silver, thallium, and zinc), five day biochemical oxygen demand (BOD5), chemical oxygen demand (COD), TOC, field pH, acidity, alkalinity, field conductivity, Total Kjeldahl Nitrogen (TKN), ammonia, nitrate-nitrite, total phosphorus, total suspended solids (TSS), total dissolved solids (TDS), sulfate, field dissolved oxygen, pesticides/PCBs (EPA Method 608), cyanide, and total and fecal coliform. All analyses were conducted by U.S. Testing of Hoboken, New Jersey, an NJDEP approved and Resource Conservation & Recovery Act (RCRA) permitted laboratory.

All results of the supplemental sampling and analysis are contained in Table 5-3. Table 5-4 contains a summary of analytical results obtained from testing of pump test water samples collected at hour 24 from APT wells 2 and 3 along with a summary of ground water quality data obtained from monitoring wells S-1 and S-3 during the RI and the Interim Environmental Monitoring Program (IEMP). Monitoring wells S-1 and S-3 are located near APT wells 2 and 3. APT wells 2 and 3 contained the most significant chemical constituents present in ground water monitoring wells during the RI.

Ground water samples collected from APT wells 2 and 3 contained lower concentrations of volatile organics than those reported for adjacent

TABLE 5 - 3

Combe Fill South Landfill
Ground Water Treatability Study

Analytical Results from 24 and 48 Hour Aquifer Pump Tests

	DETECT LIMIT	CFS PT-1 24 hr	CFS PT-1 48 hr	CFS PT-2 24 hr	CFS PT-2 48 hr	CFS PT-3 24 hr	CFS PT-3 48 hr	CFS PT-4 24 hr	CFS PT-4 48 hr
VOLATILE ORGANICS (ppb)									
chloroethane	10	U	U	13	12	U	9J	U	U
methylene chloride	5	U	U	100	6J	1J	U	U	U
acetone	10	U	U	90	96	13	38	U	U
trans-1,2-dichloroethene	5	U	U	4J	4J	U	U	U	U
chloroform	5	5	9	U	U	U	U	47	54
2-butanone	10	U	U	230	230	U	U	U	U
1,2-dichloropropane	5	U	U	3J	3J	U	U	U	U
benzene	5	5	10	16	15	U	U	U	U
4-methyl-2-pentanone	10	U	U	33	3J	U	1J	U	U
2-hexanone	10	U	U	8J	7	U	4J	U	U
toluene	5	U	U	190	150	U	U	U	U
chlorobenzene	5	22	33	52	47	U	U	U	U
ethylbenzene	5	U	U	7J	6	U	U	U	U
total xylenes	5	U	U	13	13	U	4J	U	U
PESTICIDES AND PCBs (ppb)		U	U	U	U	U	U	U	U
METALS (ppb)									
aluminum		1738	75.48			1940	958	44U	44U
antimony		33U	33U	124.1	129.5	33U	33U	88.4	125
arsenic		4.8U	4.8U	93.8	106	4.8U	4.8U	4.8U	4.8U
barium		1408	1918			638	634	12.28	75.88
beryllium		1.5U	1.5U	4.38	2.98	1.5U	1.5U	1.5U	4.38
cadmium		3.5U	3.5U	8.9	9.4	3.5U	3.5U	6.6	9.2
calcium		106000	153000	148000	153000	148000	116000	5920	6120
chromium		5.98	12.8	7.18	6.48	10.8	9.78	5.2U	5.2U
cobalt		21.48	29.68			36.98	31.68	3.48	4.28
copper		9.3U	9.3U	9.3U	79.7	9.3U	9.3U	9.3U	9.3U
iron		6350	8840	57100	54100	60100	70100	678	104
lead		5U	5U	5U	37.2	5U	5U	5U	5U
magnesium		37100	56200	69600	73100	75200	73800	25408	26508
manganese		13300	19200			6820	6830	28.2	25.3
mercury		.2U	.2U			.2U	.2U	.2U	.2U
nickel		12.4U	12.4U	12.4U	201	12.4U	12.4U	12.4U	12.4U
potassium		47508	6670			17200	20900	9478	10208
selenium		5U	5U	35U	35	5U	5U	5U	5U
silver		6.7U	6.7U	6.7U	6.7U	6.7U	6.7U	6.7U	6.7U
sodium		234000	341000			23600	1130000	6080	6140
thallium		9.1U	9.1U	9.1U	9.1U	9.1U	9.1U	9.1U	9.1U
vanadium		4.5U	4.5U			4.5U	4.5U	4.5U	4.5U
zinc		93.1	108	91.3	276.7	44.8	51.3	23.0	12.38
cyanide		10U	10U	10U	10U	10.0U	10.0U	10U	10U
phenols		5U	5U	5U	5U	5.0U	5.0U	5U	5U

TABLE 3-3 (Cont'd)

Combe Fill South Landfill
Ground Water Treatability Study

Analytical Results from 24 and 48 Hour Aquifer Pump Tests

	CFS PT-1 24 hr	CFS PT-1 48 hr	CFS PT-2 24 hr	CFS PT-2 48 hr	CFS PT-3 24 hr	CFS PT-3 48 hr	CFS PT-4 24 hr	CFS PT-4 48 hr
FILTERED METALS (ppb)								
aluminum	1838	729			347	44U	44U	44U
antimony	33U	33U	121.3	131.1	33U	33U	107	112
arsenic	4.8U	4.8U	85.1	88.7	4.8U	4.8U	4.8U	4.8U
barium	225	220			574	7.3B	8.9B	8.7B
beryllium	1.5U	1.5U	2.4B	4.3B	1.5U	1.5U	3.3B	4.3B
cadmium	3.5U	3.5U	10.1	9.0	3.5U	3.5U	7	9.2
calcium	169000	162000	149000	156000	157000	20400B	5920	5960
chromium	30.1	13.8	10.4	11.3	5.2U	5.2U	5.2U	5.2U
cobalt	30.4B	28.5B			32.1B	2.8U	2.8B	3.5B
copper	9.3U	9.3U	9.3U	9.3U	9.4B	9.3U	9.3U	9.3U
iron	9490	11900	21600	26900	53400	226	4.8U	12.5B
lead	5U	5U	5U	5U	5U	5U	5U	5U
magnesium	64300	60800	70900	74100	80300	5590B	25300B	25900B
manganese	21000	19600			7010	18.5	24.5	21.6
mercury	.2U	.2U			.2U	.2U	.2U	.2U
nickel	12.4U	12.4U	12.4U	12.4U	12.4U	12.4U	12.4U	12.4U
potassium	7490	7080			17700	17800	9030B	9800B
selenium	5U	5U	35U	35U	5U	5U	5U	5U
silver	6.7U	6.7U	6.7U	6.7U	6.7U	6.7U	6.7U	6.7U
sodium	377000	357000			259000	1600000	6040	6050
thallium	9.1U	9.1U	9.1U	9.1U	9.1U	9.1U	9.1U	9.1U
vanadium	4.5U	4.5U			4.5U	4.5U	4.5U	4.5U
zinc	124	135	104.1	363.9	61.7	5.1B	4.8B	17.3B
cyanide	10U	10U	10U	10U			10U	10U
phenols			5U	5U			5U	5U
pH	6.59	6.77	6.44	6.23	6.59	6.95		
TSS (mg/l)	26	24	3	12	60	27	1.0	2.0
TDS (mg/l)	1507	1469	1364	1416	1314	1326	121	64
specific conductance (umhos/cm)	1970	2100	1810	1936	1950	2100		
chloride (mg/l)	564	580						
nitrite (mg/l)	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
nitrate (mg/l)	5.6	5.6	5.7	1.8	2.7	3.0	0.45	0.47
COD (mg/l)	141.4	141.4	116.7	144.4	126.6	135.3	11.8	7.9
TKN (mg/l)	3.99	2.24	<0.28	<0.28	16.52	2.24	<0.14	<0.14
ammonia (mg/l)	<0.1	<0.1	<0.1	<0.1	8.35	1.43	<0.1	<0.1
sulfate (mg/l)	2.4	3.7	11.8	16.6	1.8	1.6	4.4	3.8
alkalinity (mg/l)	440	448	485	523	595	596	22.0	28.0
acidity (mg/l)	135	46	329	464	223	51	1.0	1.0
TOC (mg/l)	64.6	68	145.8	149	70.7	58.5	12.3	10.5
[illegible]phorous (mg/l)	1.48	<0.2	0.315	<0.2	1.30	0.59	0.82	0.90
[illegible] (mg/l)	<10	<10	68	63	<10	15	<10	<10
total coliform bacteria (mpn/100ml)	<2	<2	<2	<2	13	<2	<2	<2

U - Undetected

B - Also Detected in Blank

J - Detected, but Below Method Detection Limit

TABLE 5-4

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

GROUND WATER CHARACTERISTICS (1986, 1988, 1989)

			RI		IEMP		Aquifer Pump Test		Treatability Study					
COMPOUND	Unit	Detection Limit (YORK)	S-1(PT-3) 5/86 (LMSE)	S-3(PT-2) 5/86 (LMSE)	S-1(PT-3) 12/88	S-3(PT-2) 12/88	PT-2* 12/1/88 (US TESTING)	PT-3* 12/1/88 (US TESTING)	COMP. PT-2/PT-3** 3/27/89 (YORK)	COMP. PT-2/PT-3** 4/17/89 (YORK)	COMP. PT-2/PT-3** 5/05/89 (YORK)	COMP. PT-2/PT-3** 5/19/89 (YORK)	COMP. PT-2/PT-3** 6/02/89 (YORK)	COMP. PT-2/PT-3** 6/15/89 (YORK)
hloroethane	ug/l	10	U	10J	U	U	13	U	U	U	U	U	U	U
ethylene Chloride	"	5	56	18.4	3J	U	100	1J	6	5	4JB	3J	U	U
cetone	"	10	-	-	240	U	90	13	-	U	U	U	U	U
arbon Disulfide	"	5	-	-	3J	U	-	-	-	-	-	U	U	U
inyl Acetate	"	10	-	-	11	U	-	-	-	-	-	U	U	U
-1,2-Dichloroethene	"	5	U	8.02	-	-	4J	U	-	U	U	U	U	U
,1-Dichloroethane	"	5	65.2	51.4	-	-	U	U	U	U	U	U	U	U
,2-Dichloroethane	"	5	U	U	-	-	U	U	U	U	U	U	U	U
richloroethylene	"	5	U	4.04	-	-	U	U	U	U	41	22	22	U
etrachloroethylene	"	5	U	4.1J	-	-	U	U	U	U	U	U	U	U
-Butanone	"	10	-	-	-	-	230	U	-	U	U	U	U	U
,2-Dichloropropane	"	5	U	6J	-	-	3J	U	U	U	U	U	U	U
enzene	"	5	64.7	80.2	44	U	16	U	10	10	7	6	4J	3J
-Methyl-2-Pentanone	"	10	-	-	32	U	33	U	-	U	U	U	U	U
-Hexanone	"	10	-	-	6J	U	8J	U	-	U	U	U	U	U
oluene	"	5	1370	68.2	130	U	190	U	42	42	57	42	12	28
hlorobenzene	"	5	U	21.1	27	U	52	U	25	25	17	15	18	14
thylbenzene	"	5	U	7.2J	12	U	7J	U	5	5	11	27	3J	2J
otal Xylenes	"	5	-	-	33	U	13X	U	-	-	-	U	U	U
inyl Chloride	"	10	U	10J	_	_	U	U	U	U	U	U	U	U
H	S.U.	-	-	-	6.4	6.1	6.4	6.5	6.2	-	-	-	-	-
SS	mg/l	-	-	-	217	99	3	60	330	21	18	18	19	47
DS	"	-	-	-	1454	2396	1364	1314	-	-	-	-	-	-
OC	"	-	-	-	-	-	145.8	70.7	58	61	52	11	57	181
OD	"	-	-	-	113.2	863.8	116.6	126.6	-	-	-	-	-	-
OD5	"	-	-	-	64	530	68	<10	61	58	55	9	53	45
mmonia	"	-	-	-	<0.1	<0.1	<0.1	8.35	8.8	8.8	8.18	8.9	12.5	11.8
KN	"	-	-	-	2.17	<0.28	<0.28	16.52	-	-	-	-	-	-
	"	-	-	-	0.96	1.67	0.315	1.3	-	-	-	-	-	-

* Samples collected during pump test (24 hr).
** Samples collected for treatability studies & composited at equal volume.
U Undetected
J Detected but less than method detection limit
B Also detected in blank

ground water monitoring wells S-1 and S-3 during the RI and IEMP. For example, 1,1 dichloroethane, found at approximately 65 ug/L and 51 ug/L respectively in monitoring well S-1 and S-2 during the RI, was not found in detectable quantities in either APT well 2 or 3. A number of factors could explain the observed differences between volatile organic data obtained during the RI and the APT, including: a depletion of the source of volatile organics, differences between APT well and monitoring well construction (i.e., well segments screened), and differences in ground water recharge and flow brought about by differences in rainfall received at the site prior to sampling.

Metals data generated from APT well samples were similar to those collected from the monitoring wells during the RI. Heavy metals of concern include nickel and zinc which were present in ground water. Samples from APT wells at concentrations ranging from less than 12.4 ug/L to 201 ug/L and from 4.8 ug/L to 364 ug/L, respectively.

BOD5 values for ground water samples from APT wells were lower than values reported during the IEMP (approximately 58 mg/L compared to greater than 100 mg/L).

Landfill capping is expected to severely limit leachate generation. Existing ground water in the vicinity of the fill is affected by leachate. Future ground water quality should improve over time due to reduced leachate generation.

The landfill gas condensate (LGC) volume anticipated as part of the treatment plant influent has been estimated by an evaluation of the volume and the timing associated with the placement of solid waste at the landfill and the technical literature available on the subject. Landfill gas condensate is a two-phase liquid containing an aqueous and an organic phase of variable proportion depending on the site.

Condensate quality in terms of BOD5, TOC, and COD varies considerably among sites and, in general, is similar to landfill leachate with a BOD5 ranging from 1,000 to 30,000 mg/L, and COD and TOC concentrations present as a multiple of BOD5 concentrations. This multiple typically ranges from 2 to 10, depending on the composition and age of landfill contents.

Table 5-5 indicates condensate quality which would be expected based on similar sites. Table 5-6 contains actual landfill gas condensate characterization data for the Combe Fill South Landfill. Condensate samples were collected on September 6 and 7, 1989. These samples were characterized by York Laboratories of Monroe, Connecticut for BOD5, COD, TOC, phosphorus, ammonia-nitrogen, TKN, nitrate-nitrogen, and volatile organics. The results of sampling and characterizing one sample of Combe Fill South Landfill LGC suggest that a low-strength LGC might be expected.

Calculations performed utilizing the thermodynamic properties of saturated air indicate that for an flow rate of 2,000 cubic feet per minute (CFM) at an temperature of 100° Fahrenheit, approximately 1,000 gallons per day of water would be condensed. If the temperature rises to 150°F, approximately 3,600 gallons per day of water would be generated. If the flow rate increases to 3,000 CFM, approximately 1,500 gallons per day of water

TABLE 5 -5
COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

EXPECTED LANDFILL GAS CONDENSATE CHARACTERISTICS

PARAMETER	UNITS	VALUE
Condensate Flow	gpd	5,000
BOD5	mg/l	10,000
COD	mg/l	20,000
TOC	mg/l	10,000
TSS	mg/l	<25
Total Metals	mg/l	<0.25
VOC	mg/l	10
Total Phenolics	mg/l	10

TABLE 5-6

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

ACTUAL LANDFILL GAS CONDENSATE CHARACTERISTICS
SAMPLES COLLECTED 9/6-7/89

CONVENTIONAL PARAMETERS

PARAMETER	CONCENTRATION (mg/l)
Ammonia-Nitrogen	23.8
Biochemical Oxygen Demand (5 day)	12
Chemical Oxygen Demand	98.8
Nitrate-Nitrogen	<0.10
Phenols	0.092
Phosphorus, total	<0.15
Total Kjeldahl Nitrogen	24.2
Total Organic Carbon	24.8

VOLATILE ORGANICS

PARAMETER	METHOD DETECTION LIMIT (ug/l)	CONCENTRATION (ug/l)
Chloromethane	10	U
Bromomethane	10	U
Vinyl Chloride	10	U
Chloroethane	10	U
Methylene Chloride	5	10B
Acetone	10	U
Carbon Disulfide	5	U
1,1-Dichloroethene	5	U
1,1-Dichloroethane	5	U
1,2-Dichloroethene (total)	5	U
Chloroform	5	U
1,2-Dichloroethane	5	U
2-Butanone	5	U
1,1,1-Trichloroethane	10	U
Carbon Tetrachloride	5	U
Vinyl Acetate	5	U
Bromodichloromethane	10	U
1,2-Dichloropropane	5	U
c-1,3-Dichloropropene	5	U
Trichloroethene	5	U
Dibromochloromethane	5	U
1,1,2-Trichloroethane	5	U
Benzene	5	U
t-1,3-Dichloropropene	5	U
Bromoform	5	U
4-Methyl-2-pentanone	10	U
2-Hexanone	10	U
Tetrachloroethene	5	U
1,1,2,2-Tetrachloroethane	5	U
Toluene	5	21
Chlorobenzene	5	3J
Ethylbenzene	5	16
Styrene	5	U
Xylene (total)	5	33

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

would be condensed at a temperature of 100° F and approximately 5,400 gallons per day of water would be generated at a temperature of 150°F.

Although the above temperatures are greater than the temperatures measured at two wells installed in the Combe Fill South Landfill, information presented in Methane Generation and Recovery from Landfills by Emcon Associates [2], indicate that temperatures in landfills 15 meters (49 feet) in thickness have been observed as high as 70° C (158° F). In a paper titled "Landfill Gas Condensate and Its Disposal" by Ronald J. Lofy [3] landfill gas temperatures from 70° F to 150° F are reported. Therefore, it may be possible to encounter landfill gas temperatures as high as 150° F at Combe Fill South Landfill.

In a paper titled "Municipal Landfill Gas Condensate" prepared in 1987 by SCS Engineers, Inc. [4] for the Environmental Protection Agency, actual condensate generation rates from operating landfill gas systems are reported as ranging from 44 to 162 liters per 1,000 cubic meters of unprocessed landfill gas which converts to 329 to 1,211 gallons per million cubic feet of gas extracted. This, in turn, converts to quantities of condensate ranging from approximately 950 to 3,500 gallons per day for a gas flow rate of 2,000 CFM and from 1,425 to 5,250 gallons per day for a flow rate or 3,000 CFM. Lofy recommends designing for a flow rate of 1,400 gallons per million cubic feet of gas extracted which converts to quantities of 4,000 gallons per day for an extraction rate of 2,000 CFM and 6,000 gallons per day for an extraction rate of 3,000 CFM.

When the Ground Water Treatment Facility Preliminary Design Report was prepared in September of 1989, the design gas extraction rate was 3,000 CFM. Based on input from NJDEP, the design rate has been modified to 2,000 CFM with the extraction system having the ability to handle up to 3,000 CFM. Given the reported literature values for landfill gas and condensate generation rates, a condensate design flow rate of 5,000 gallons per day has been selected in order to insure that adequate treatment capacity will be available.

5.02.04 Evaluation of Alternatives

Ground water and leachate data generated during the RI (Tables 5-1 and 5-2) along with the proposed effluent discharge limitations (Table 5-2) indicate that treatment must provide for removal of: BOD5, TSS, TOC, ammonia-nitrogen, volatile organics, heavy metals, and total phenolics. The Final Conceptual Design Report [1] suggested the following train of unit processes for the treatment of ground water collected from the Combe Fill South Landfill: hydraulic equalization, chemical precipitation of heavy metals, biological treatment of organics, dual media filtration, and activated carbon adsorption polishing.

Recent studies [5,6] demonstrated the cost effectiveness of using powdered activated carbon (PAC) assisted biological treatment of contaminated ground water and leachate. This technology combines the essential elements of three of the recommended unit operations for treating ground water at the site: biological treatment of organics, filtration of solids, and carbon adsorption polishing of organics. Another recent study [7] documented the effectiveness of combining the PAC biological treatment concept with sequencing batch reactors (SBR). Such a system provided excellent effluent quality, operational flexibility, and low operator attention making it a favorable option for treatment of ground water. Therefore, bench scale testing for biological treatment of ground water involved SBRs combined with PAC enhanced biological treatment.

5.02.05 Treatability Testing Approach

All treatability testing was performed in the pilot study facilities located in O'Brien & Gere's Syracuse office. Analytical testing was conducted by York Laboratories of Monroe, Connecticut. All analytical testing performed in association with the treatability studies conformed to the contract required detection limits. Table 5-7 lists the method detection limits.

Ground water samples were obtained in equal volume portions from APT wells 2 and 3 once every two weeks. These samples were composited and transported to O'Brien & Gere's Syracuse office for storage at 4 degrees Celsius prior to treatability testing. Ground water from APT wells 2 and 3 was selected for treatability testing based on the presence of these wells in the area of the site which has shown the highest levels of organic and inorganic substances in the ground water.

Testing was completed for most unit operations contained on Figure 5-1. Polishing filtration and air stripping tests were not performed on the biological treatment systems' effluents. The TSS of the biological treatment

TABLE 5-7

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY
METHOD DETECTION LIMITS

VOLATILE ORGANIC COMPOUNDS

Compound	Method Detection Limits with no Dilution (ppb)
Chloromethane	10
Bromomethane	10
Vinyl chloride	10
Chloroethane	10
Methylene Chloride	5
Trichlorofluoromethane	10
acrolein	100
acrylonitrile	35
1,1-dichloroethene	5
1,1-dichloroethene (total)	5
Chloroform	5
1,2,dichloroethane	5
Bromodichloromethane	5
1,2-dichloropropane	5
Cis-1,3-dichloropropene	5
2-chloroethylvinyl ether	5
Trichloroethylene	5
Dibromochloromethane	5
1,1,2-trichlorethane	5
Benzene	5
Trans-1,3-dichloropropene	5
Bromoform	5
Tetrachloroethylene	5
1,1,2-2-tetrachloroethane	5
Toluene	5
Chlorobenzene	5
Ethyl benzene	5

TABLE 5-7

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY
METHOD DETECTION LIMITS

SEMI-VOLATILE ORGANICS

Compound	Method Detection Limits with no Dilution (ppb)
N-nitrosodimethyl amine	10
bis (2-chloroethyl) ether	10
1,3-dichlorobenzene	10
1,4-dichlorobenzene	10
1,2-dichlorobenzene	10
bis (2-chloroisopropyl) ether	10
hexachloroethane	10
N-nitroso-di-n-propylamine	10
nitrobenzene	10
isophorone	10
bis (2-chloroethoxy) methane	10
1,2,4-trichlorobenzene	10
naphthalene	10
hexachlorobutadiene	10
hexachlorocyclopentadiene	10
2-chloronaphthalene	10
dimethyl phthalate	10
acenaphthylene	10
2,6-dinitrotoluene	10
acenaphthene	10
2,4-dinitrotoluene	10
diethyl phthalate	10
fluorene	10
4-chlorophyenl-phenyl ether	10
4-bromophenyl-phenyl ether	10
N-nitrosodiphenylamine(1)	10
hexachlorobenzene	10
phenanthrene	10
anthracene	10
di-n-butyl phthalate	10
fluoranthene	10
benzidine	80
pyrene	10
butyl benzyl phthalate	10
3,3-dichlorobenzidine	20
chrysene	10
benzo(a)anthracene	10
bis(2-ethyl hexyl) phthalate	10
di-n-octyl phthalate	10

TABLE 5-7

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY
METHOD DETECTION LIMITS

SEMI-VOLATILE ORGANICS
(Continued)

Compound	Method Detection Limits with no Dilution (ppb)
benzo(b)fluoranthene	10
benzo(k)fluoranthene	10
benzo(a)pyarene	10
benzo(g,h,i)perylene	10
dibenzo(a,h)anthracene	10
Indeno(1,2,3,c,d)pyrene	10
1,2-diphenylhydrazine(2)	10
phenol	10
2-chlorophenol	10
2-nitrophenol	10
2,4-dimethylphenol	10
2,4-dichlorophenol	10
2,4-dichlorophenol	10
4-chloro-3-methyl phenol	10
2,4,6-trichlorophenol	10
2,4-dinitrophenol	50
4-nitrophenol	50
2-methyl-4,6-dinitrophenol	50
pentachlorophenol	50

TABLE 5-7

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY
METHOD DETECTION LIMITS

PESTICIDES/PCBs

Compound	Method Detection Limits with no Dilution (ppb)
alpha BHC	0.01
beta BHC	0.01
gamma BHC	0.01
delta BHC	0.01
Heptachlor	0.01
Aldrin	0.01
4,4' DDE	0.01
Dieldrin	0.01
4,4' DDD	0.05
Endrin Aldehyde	0.05
4,4' DDT	0.05
Chlorodane	0.10
Endosulfan I	0.01
Endosulfan II	0.05
Endosulfan Sulfate	0.05
Endrin	0.05
Heptachlor Epoxide	0.01
Toxaphene	1.0
PCB - 1016	0.20
PCB - 1221	0.20
PCB - 1232	0.20
PCB - 1242	0.20
PCB - 1248	0.20
PCB - 1254	0.20
PCB - 1260	0.20

TABLE 5-7

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY
METHOD DETECTION LIMITS

METALS

Compound	Method Detection Limits with no Dilution (ppb)
Antimony	60.0
Arsenic	10
Beryllium	5.0
Cadmium	10
Chromium	10
Copper	25
Iron	100
Lead	5
Mercury	0.20
Nickel	40.0
Selenium	5.0
Silver	10
Thallium	10
Zinc	20

systems' effluents were sufficiently low (generally less than 8 mg/l) to render filtration polishing unnecessary prior to granular activated carbon (GAC) testing.

Volatile organic concentrations in the effluents from the bench scale SBRs were non-detectable or at or below the detection limit of 5 ug/l for six out of the seven days sampled (Section 5.02.07). Methylene chloride was found in effluents from two SBRs at 7 and 8 ug/l on May 10, 1989, but it was also found in the blank. These observations indicate that VOCs were effectively removed from the ground water by the SBRs. Therefore, air stripping testing was not performed.

Landfill gas condensate (LGC) was recognized as a component of the future wastestream after the initiation of the treatability studies. However, the volume of LGC produced from a small scale gas withdrawal test was insufficient to conduct reasonably scaled biological treatability studies (one liter of feed per day or greater).

5.02.06 Metals Removal

Since effluent requirements for metals are generally less than the solubility limits for metal hydroxides, co-precipitation with iron was evaluated for removal of heavy metals. Jar tests were conducted to evaluate the effectiveness of pH adjustment and ferric sulfate addition for heavy metals removal. Precipitation tests were conducted over the pH range of minimum heavy metals solubility (8.5 - 10.0). Three pH levels (8.5, 9.5, and 10 S.U.) and four ferric sulfate dosages (0, 50, 100, and 200 mg/L) were used in the study. The analytical program involved testing for influent and effluent TSS, pH, and selected heavy metals.

Heavy metals precipitation jar tests were conducted using a standard six-paddle jar testing device. A 1000 milliliter (ml) sample of ground water was placed in a 1500 ml beaker and rapidly mixed (100 rpm). Ferric sulfate was added to the ground water sample and the pH was adjusted using 1N sodium hydroxide. At a ferric sulfate dose of 100 mg/l, alkalification of ground water to pH 8.5, 9.5, and 10.0 S.U. required 14.4, 24.0, and 29.0 ml., respectively, of 1N sodium hydroxide solution. The contents of the beakers were rapidly mixed (100 rpm) for 30 seconds and then flocculated (30 rpm) for 15 minutes. The resulting metal hydroxide and iron floc was allowed to settle for approximately one hour and the resulting supernatants were analyzed for TSS, pH, and selected heavy metals.

The chemical addition regime producing the best metals removal efficiency was further tested to evaluate the corresponding sludge generation rates and sludge settling characteristics. A settling column test was conducted by employing a five foot long, eight inch diameter settling column and adding 0.5 mg/L of anionic polyelectrolyte (M835A) to enhance sludge settling. The interface depth (ft) versus settling time (min) was recorded over a 2 hour period and plotted to determine sludge settling rates. The volume of settled sludge and corresponding solids concentration was recorded along with supernatant pH and TSS.

Table 5-8 presents the results of ground water heavy metals co-precipitation with ferric sulfate. All of the dosage schemes reduced ground water chromium, copper, and lead from pretreatment values of 25.8, 45.4, and 5.5 ug/L, respectively, to less than the corresponding method detection limits (10, 25, and 5 ug/L, respectively). Zinc data generated from the co-precipitation study indicates that a ferric sulfate dose of at least 50 mg/L as iron is required to effectively eliminate zinc from the ground water. Zinc precipitation was relatively insensitive to pH over the range employed for this study (8.5 - 10 S.U.) as indicated by the insignificant difference between dosage schemes employing the same ferric sulfate dose at different pH values. The TSS of the ground water was reduced from a pretreatment concentration of 330 mg/L to less than 16 mg/L for all dosage schemes, with greater reduction occurring at pH 8.5.

Heavy metals characterization of ground water prior to precipitation testing involved only those metals considered an issue at the CFSL, based on results presented in the Remedial Investigation Report. Laboratory characterization of treated ground water indicates that other heavy metals, if present in the ground water, were effectively removed by precipitation at pH 8.5.

Based upon these results, a ferric sulfate dose of 100 mg/L and a pH of 8.5 was chosen as the optimal heavy metals pretreatment for Combe Fill South Landfill ground water. A ferric sulfate dose of 100 mg/l was selected to remove heavy metals to concentrations below effluent discharge limitations. During the precipitation jar tests, chromium, copper, and lead were effectively removed from composite ground water at all pHs and ferric sulfate doses employed. Zinc was not consistently removed from solution at the 50 mg/l

TABLE 5-8

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE PRECIPITATION TESTING RESULTS

SAMPLE	Fe3+ mg/l	pH S.U.	Sb ug/l	As ug/l	Be ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Hg ug/l	Ni ug/l	Se ug/l	Ag ug/l	Tl ug/l	Zn ug/l	TSS mg/l
COMP.GW	-	-	-	-	-	-	25.8	45.4	87,800	5.5	-	<40	-	-	-	166	330
CFS1-1	0	8.5	-	-	-	-	<10	<25	224	<5	-	<40	-	-	-	23.8	<1
CFS1-2	50	8.5	-	-	-	-	<10	<25	190	<5	-	<40	-	-	-	<20	2
CFS1-3	100	8.5	-	-	-	-	<10	<25	897	<5	-	<40	-	-	-	<20	8
CFS1-4	200	8.5	<60	<10	<5	<10	<10	<25	477	<5	<0.2	<40	<5	<10	<10	<20	<1
CFS1-5	0	9.5	<60	<10	<5	<10	<10	<25	199	<5	<0.2	<40	<5	<10	<10	25.6	<1
CFS1-6	50	9.5	-	-	-	-	<10	<25	105	<5	-	<40	-	-	-	36.1	16
CFS1-7	100	9.5	-	-	-	-	<10	<25	237	<5	-	<40	-	-	-	22	14
CFS1-8	200	9.5	<60	<10	<5	<10	<10	<25	238	<5	<0.2	<40	<5	<10	<10	<20	3
CFS1-9	0	10	-	-	-	-	<10	<25	110	<5	<0.2	<40	-	-	-	<20	14
CFS1-10	50	10	-	-	-	-	<10	<25	152	<5	-	<40	-	-	-	41.3	12
CFS1-11	100	10	-	-	-	-	<10	<25	143	<5	-	<40	-	-	-	<20	12
CFS1-12	200	10	<60	<10	<5	<10	<10	<25	173	<5	<0.2	<40	<5	<10	<10	<20	2

ferric sulfate dose at pH values of 9.5 or 10.5. Therefore, as a conservative approach, it was decided to dose with 100 mg/l ferric sulfate at a pH of 8.5 in order to consistently provide optimal zinc removals. This pretreatment method was used to prepare feed to the bench-scale SBR requiring removal of heavy metals (Alternatives A and C, Figure 2-1). Table 5-9 contains the pretreatment conditions used to prepare the pretreatment feeds for the SBRs.

Figure 5-3 presents the results of the settling column study performed on sludge generated from heavy metals pretreatment of site ground water. Approximately 2000 ml of iron and metal hydroxide sludge produced at pH 8.5 and ferric sulfate dose of 100 mg/l and conditioned with 0.25 mg/l anionic polymer (American Cyanamid 835A) was added to a 2000 ml graduated cylinder. The sludge interface depth, chosen as the distance from the air-water interface to the sludge interface, was monitored with time. Figure 5-3 depicts the depth of the settling sludge interface as a function of settling time in minutes. The initial settling velocity, as calculated from the slope of the first linear section of the curve, is approximately 0.5 feet per minute. This initial settling velocity was used to size the inclined plate clarifier proposed for removal of sludge generated from ground water pretreatment.

5.02.07 Biological Treatment

The efficiency and efficacy of biological treatment of the ground water was evaluated using sequencing batch reactors. Three two liter volume SBRs were operated in a fill and draw mode for 15 weeks according to the cycle time composition schedule appearing in Table 5-10. This operation produced

TABLE 5-9

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

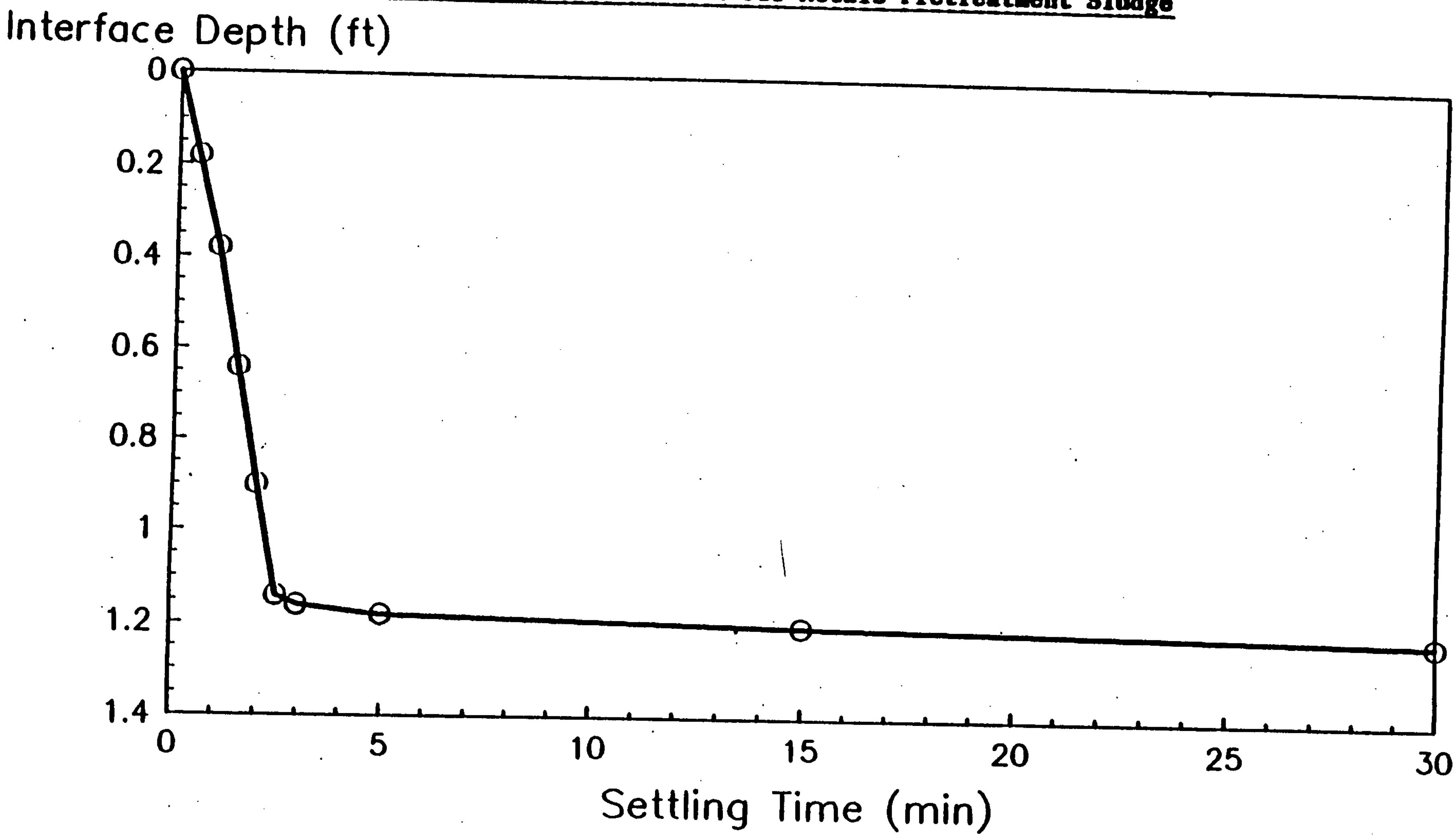
BIWEEKLY GROUND WATER SAMPLE PRE-TREATMENT CONDITIONS

Volume	: 35 liters
Fe2(SO4)3	: 100 mg/l as Fe
Initial pH range	: 6.0 - 6.5 S.U.
Average 50% NaOH added	: 19.3 ml
Treated pH	: 8.5 S.U.
Polymer (M835A)	: 0.25 mg/l
TSS before treated	: 434 mg/l
TSS after treated	: 569 mg/l
Settling time	: 2 hours
Supernatant TSS	: 8 mg/l
Sludge Volume	: 1.8 liters (5% v/v)
Sludge percent solids	: 1.54%

Figure 5-3

'Combe Fill South Landfill
Ground Water Treatability Study

Settling Column Test Results For Metals Pretreatment Sludge



a hydraulic retention time of 24 hours. The solids retention time was maintained at greater than 20 days.

The three SBRs represented three different treatment scenarios corresponding to treatment configurations A, C and D appearing in Figure 5-1. The three reactors received the following feed and PAC treatments:

Reactor	Feed	PAC Inventory
A	GW Pretreated for Metals	0 mg/L
C	GW Pretreated for Metals	125 mg/L
D	Raw GW	125 mg/L

(Note: Alternative B was not tested since it was assumed that sufficient data would be generated by the other tests).

Biological solids used to seed the SBRs were obtained from the activated sludge process at the Syracuse Metropolitan Wastewater Treatment Plant. No additional solids were added to the SBRs during the course of the study.

The test reactors each received full-strength CFSL ground water from the start of the bench-scale testing. Acclimation, in the sense of step feeding ground water, was not believed necessary nor desirable, since CFSL ground water was weaker than wastewater typically encountered by the seed sludge.

The SBR feed was augmented with 2 mg/day phosphorus as phosphoric acid. Phosphorus addition was based upon an expected BOD5 concentration of 100 mg/l, a BOD5 to P ratio of 100:1, and a hydraulic retention period of 24 hours. Ammonium contained within the ground water was sufficient to meet the nitrogen requirements of the microorganisms (BOD5 to N ratio of 20:1).

PAC was introduced to reactors C and D on one occasion only. The initial PAC dosage of 125 mg/L was chosen based upon the organic loading expected for the system. The raw ground water treatment scenario was evaluated in order to assess the need for metals pretreatment.

The analytical program for the SBR study consisted of the following: weekly effluent measurements of BOD5, TOC, TSS, pH, filterable ammonia-nitrogen, and volatile organics; biweekly effluent measurements of phenol and heavy metals; and a one time effluent measurement of base-neutral and acid extractable organic compounds, total cyanides, and pesticides/PCBs.

The F/M ratios employed during treatability testing ranged from about 0.05 to 0.1 grams BOD5 per gram of MLVSS. The bench-scale biological reactors were monitored for mixed liquor volatile suspended solids (MLVSS) and effluent total organic carbon (TOC) to assess whether steady-state conditions had been achieved. MLVSS was quantified on five occasions, and effluent TOC on seven occasions, during the fifteen weeks of bench-scale biological treatability testing. Further, mixed liquor samples were microscopically inspected on several occasions. Biota observed represented a typical distribution of activated sludge micro organisms including free swimmers stalked ciliates & flagellates. The results of these three types of monitoring were mixed with respect to identifying achievement of steady-state. Volatile solids levels were variable. However, effluent TOC and BOD5 concentrations

TABLE 5-10

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL REACTORS OPERATING CONDITIONS

Reactor	Feed	PAC Inventory	Cycle Settle hr	Cycle Decant hr	Cycle Feed hr	Cycle Aerate hr	Cycle Cycles/ day
A	Pretreated	0 mg/l	2	1	1	8	2
C	Pretreated	125 mg/l	2	1	1	8	2
D	Raw	125 mg/l	2	1	1	8	2

suggest that substantial destruction of oxygen demanding organics would be achieved consistently by biological treatment.

Table 5-11 contains the results of weekly analytical testing performed on the effluent of the three SBRs. BOD5 in the raw ground water and the ground water pretreated with ferric sulfate for metals precipitation ranged from 5 to 83 mg/L and 4 to 94 mg/L, respectively, with means and standard deviations of 38 mg/L and 25 mg/L for the raw ground water samples and 38 mg/L and 26 mg/L in the pretreated ground water samples.

BOD5 was reduced in all the reactor effluents by greater than 50 percent during the course of the testing (Figure 5-4). The differences in BOD removal efficiency between ferric sulfate pretreated and raw ground water feed reactors were insignificant, indicating that metals present in the ground water do not pose a toxicity problem for biological treatment systems.

On several occasions, effluent BOD5 concentrations exceeded the daily maximum effluent discharge limitation of 20 mg/l. BOD5 excursions may be attributed to several factors, including variations in influent BOD5, and biomass population adjustments (perhaps both in quantity and types) during the initial weeks of operation. Metals-pretreated feed BOD5 varied from 15 mg/l to 83 mg/l, with greater values occurring coincident with effluent BOD5 excursions. Such fluctuations in ground water BOD5 would not be expected with a full-scale ground water recovery system, due to the number of necessary wells, and the gradual fluctuations in ground water quality expected on a day-to-day basis. Further BOD5 removal is expected in filtration and carbon adsorption processes downstream from the SBRs. At the 95 percent

TABLE 5-11

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - CONVENTIONAL PARAMETERS AND METALS

DATE	SAMPLE	BOD5 mg/l	TOC mg/l	TSS mg/l	VSS mg/l	NH3N mg/l	CN mg/l	PHENOL mg/l	Sb ug/l	As ug/l	Be ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Hg ug/l	Ni ug/l	Se ug/l	Ag ug/l	Tl ug/l	Zn ug/l
4/12/89	---------- S T A R T - U P ----------																					
	REACTOR-A ML	-	-	2,415	1,945	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C ML	-	-	2,415	1,945	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D ML	-	-	2,415	1,945	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4/26/89	RAW FEED	15	-	44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	28	-	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	8	-	13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	4	-	7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	4	-	6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/03/89	RAW FEED	61	58	21	-	8.8	-	-	-	-	-	-	U	U	10,900	U	-	U	-	-	-	51.2
	PRET'D FEED	31	41	27	-	7.2	-	-	-	-	-	-	U	U	U	U	-	U	-	-	-	U
	REACTOR-A EFF	8	25	15	-	1.1	-	-	-	-	-	-	U	U	231	U	-	U	-	-	-	U
	REACTOR-C EFF	6	23	12	-	2.4	-	-	-	-	-	-	U	U	838	U	-	U	-	-	-	21.9
	REACTOR-D EFF	6	24	9	-	0.4	-	-	-	-	-	-	U	U	1,050	U	-	U	-	-	-	U
	REACTOR-A ML	-	-	852	550	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C ML	-	-	1,126	762	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D ML	-	-	4,606	990	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/10/89	RAW FEED	55	52	18	-	8.18	-	U	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	57	56	8	-	8.64	-	0.012	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	31	20	8	-	0.28	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	32	22	11	-	0.56	-	0.012	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	25	23	4	-	0.58	-	0.014	-	-	-	-	-	-	-	-	-	-	-	-	-	-

TABLE 5-11

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - CONVENTIONAL PARAMETERS AND METALS

DATE	SAMPLE	BOD5 mg/l	TOC mg/l	TSS mg/l	VSS mg/l	NH3N mg/l	CN mg/l	PHENOL mg/l	Sb ug/l	As ug/l	Be ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Hg ug/l	Ni ug/l	Se ug/l	Ag ug/l	Tl ug/l	Zn ug/l
5/17/89	RAW FEED	83	-	-	-	8.8	-	-	U	U	U	U	U	U	2,430	U	U	U	U	U	U	36.9
	PRET'D FEED	94	-	-	-	8.7	-	-	U	U	U	U	U	U	876	-	U	U	U	U	U	47.8
	REACTOR-A EFF	24	-	-	-	U	-	-	U	U	U	U	U	U	152	-	U	U	U	U	U	U
	REACTOR-C EFF	21	-	-	-	U	-	-	U	U	U	U	U	U	U	-	U	U	U	U	U	U
	REACTOR-D EFF	11	-	-	-	U	-	-	U	U	U	U	U	U	529	-	U	U	U	U	U	U
	REACTOR-A ML	-	-	1,090	420	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C ML	-	-	595	301	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D ML	-	-	2,670	514	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/24/89	RAW FEED	9	11	18	-	8.89	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	39	13	16	-	9.43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	U	4	6	-	0.23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	U	5	U	-	0.21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	5	6	U	-	0.16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5/31/89	RAW FEED	12	-	5	-	9.76	-	0.015	-	-	-	-	U	U	224	U	-	U	-	-	-	U
	PRET'D FEED	17	-	7	-	9.51	-	0.018	-	-	-	-	U	U	223	U	-	U	-	-	-	U
	REACTOR-A EFF	9	-	-	-	0.07	-	0.012	-	-	-	-	U	U	230	U	-	U	-	-	-	U
	REACTOR-C EFF	8	-	5	-	0.09	-	0.014	-	-	-	-	U	U	190	U	-	U	-	-	-	U
	REACTOR-D EFF	4	-	-	-	0.15	-	0.012	-	-	-	-	U	U	181	U	-	U	-	-	-	U

TABLE 5-11

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - CONVENTIONAL PARAMETERS AND METALS

DATE	SAMPLE	BOD5 mg/l	TOC mg/l	TSS mg/l	VSS mg/l	NH3N mg/l	CN mg/l	PHENOL mg/l	Sb ug/l	As ug/l	Be ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Hg ug/l	Ni ug/l	Se ug/l	Ag ug/l	Tl ug/l	Zn ug/l
6/07/89	RAW FEED	53	57	19	-	12.5	-	0.022	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	71	58	4	-	12.1	-	0.024	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	13	20	U	-	0.08	-	0.020	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	10	17	U	-	U	-	0.010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	12	24	U	-	0.08	-	U	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A ML	-	-	3,560	1,080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C ML	-	-	1,620	844	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D ML	-	-	4,200	1,190	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
6/14/89	RAW FEED	5	-	10	-	12.5	U	-	U	U	U	U	U	U	1,210	U	U	U	6.2	U	U	20.9
	PRET'D FEED	4	-	8	-	12.3	U	-	U	U	U	U	U	U	226	U	U	U	11.4	U	U	U
	REACTOR-A EFF	3	-	11	-	0.62	U	-	U	U	U	U	U	U	U	U	U	U	U	U	U	U
	REACTOR-C EFF	1	-	8	-	0.64	U	-	U	U	U	U	U	U	117	U	U	U	U	U	U	U
	REACTOR-D EFF	U	-	8	-	0.53	U	-	U	U	U	U	U	U	U	U	U	U	U	U	U	U
6/21/89	RAW FEED	45	181	47	-	11.8	-	0.031	-	-	-	-	U	U	20,100	U	-	U	-	-	-	26.1
	PRET'D FEED	16	38	7	-	12.4	-	0.034	-	-	-	-	U	U	368	U	-	U	-	-	-	U
	REACTOR-A EFF	2	19	5	-	0.32	-	0.024	-	-	-	-	U	U	U	U	-	U	-	-	-	U
	REACTOR-C EFF	7	24	3	-	0.62	-	0.019	-	-	-	-	U	U	135	U	-	U	-	-	-	U
	REACTOR-D EFF	3	23	5	-	0.42	-	0.013	-	-	-	-	U	U	120	U	-	U	-	-	-	U

TABLE 5-11

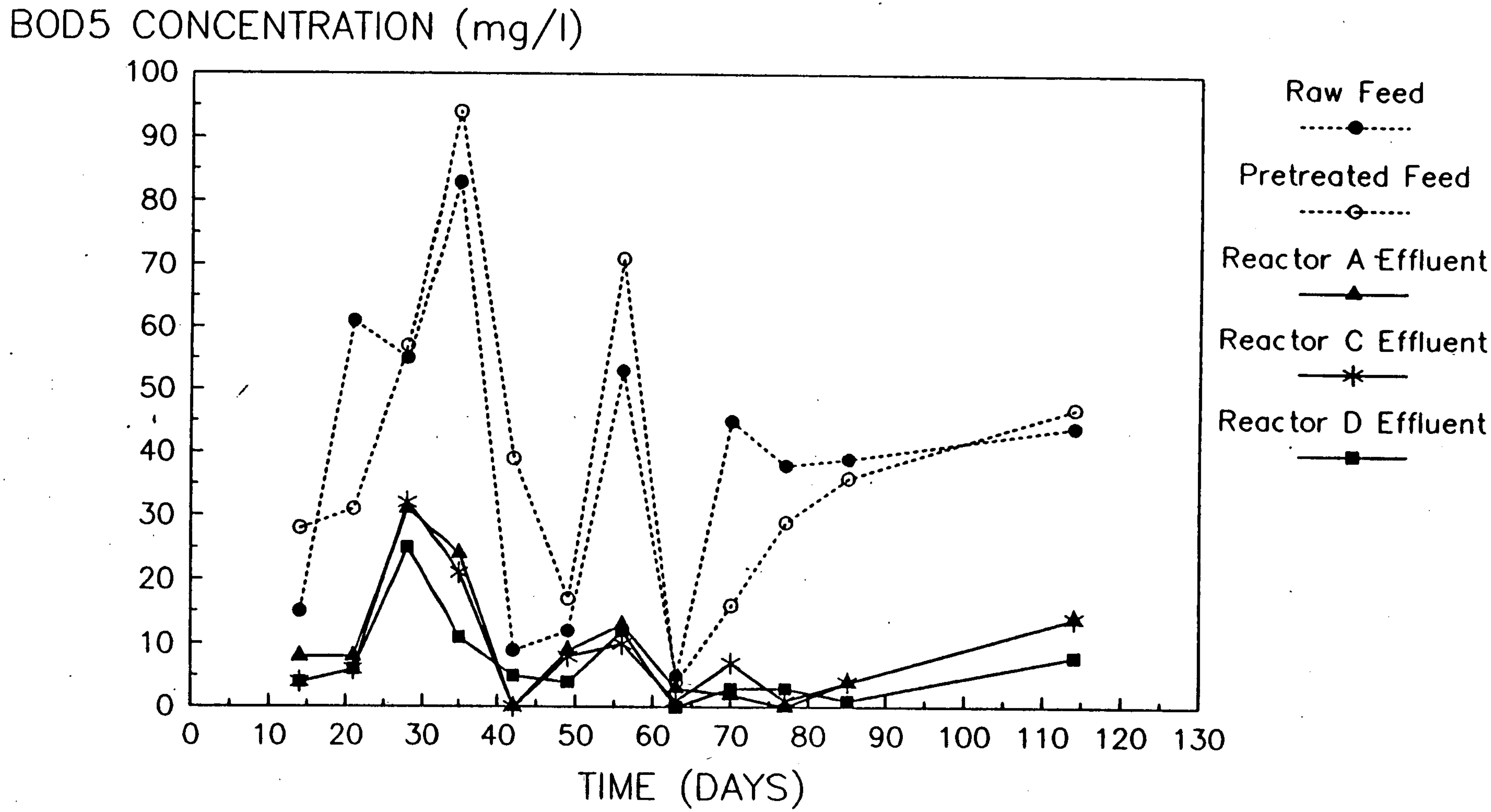
COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - CONVENTIONAL PARAMETERS AND METALS

DATE	SAMPLE	BOD5 mg/l	TOC mg/l	TSS mg/l	VSS mg/l	NH3N mg/l	CN mg/l	PHENOL mg/l	Sb ug/l	As ug/l	Be ug/l	Cd ug/l	Cr ug/l	Cu ug/l	Fe ug/l	Pb ug/l	Hg ug/l	Ni ug/l	Se ug/l	Ag ug/l	Tl ug/l	Zn ug/l
6/28/89	RAW FEED	38	-	16	-	6.98	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	29	-	3	-	7.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	U	-	6	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	1	-	11	-	0.51	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	3	-	5	-	0.56	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A ML	-	-	2,520	702	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C ML	-	-	2,350	929	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D ML	-	-	6,980	818	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7/06/89	RAW FEED	39	66.4	128	-	11.2	-	0.034	U	U	U	U	U	U	7,200	U	U	U	U	U	U	25.3
	PRET'D FEED	36	59.1	4	-	10.9	-	0.024	U	U	U	U	U	U	311	U	U	U	U	U	U	U
	REACTOR-A EFF	4	15.1	3	-	0.07	-	0.02	U	U	U	U	U	U	1,940	U	U	U	U	U	U	20.4
	REACTOR-C EFF	4	19.9	6	-	0.14	-	0.018	U	U	U	U	U	U	109	U	U	U	5.3	U	U	U
	REACTOR-D EFF	1	21.2	2	-	0.08	-	0.029	U	U	U	U	U	U	U	U	U	U	U	U	U	U
8/04/89	RAW FEED	44	52.8	22.5	-	13.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	PRET'D FEED	47	55.0	2.4	-	14.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-A EFF	14	33.4	6.6	-	0.27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-C EFF	14	29.7	U	-	0.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	REACTOR-D EFF	8	28.9	1.3	-	0.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

FIGURE 5 –4

INFLUENT AND EFFLUENT BOD5



confidence level, there is no significant difference between the three reactors' effluent BOD5 concentrations. The results of the treatability data (Table 5-11) indicate the ability of the system to treat influent ground water with BOD concentrations less than 40 mg/L.

TSS loadings to the SBRs fluctuated with time ranging from 3 to 47 mg/L for the raw ground water and 3 to 27 mg/L for the ferric sulfate pre-treated ground water. The lower TSS of the ferric sulfate ground water results from TSS removal during pretreatment. The removal trends of TOC and TSS generally followed those of BOD5 with only insignificant differences between the different treatment scenarios. Ammonia-nitrogen levels were generally reduced from feed concentrations which ranged from 7.0 to 12.5 mg/L to generally less than 1 mg/L. Phenols were not detected (less than 0.05 mg/l) in any of the influent or effluent samples.

Zinc, present in the raw feed at concentrations ranging from less than the 5 ug/L detection limit to 51 ug/L, was typically reduced to less than the detection limit via biological treatment. These results suggest that biological treatment of the raw ground water may be adequate to treat heavy metals. However, higher metals concentrations in ground water may be evident in the future, therefore metal pretreatment by iron hydroxide co-precipitation would be a prudent precursor to biological treatment.

Table 5-12 contains the results of weekly volatile organic compound scans of SBR influents and effluents. VOCs present in the SBR influents were methylene chloride, 1,2 dichloroethane, benzene, toluene, chlorobenzene, and ethylbenzene which ranged from 3 to 8 ug/L, undetectable

(UD) to 91 ug/L, UD to 10 ug/L, 9 to 140 ug/L, 6 to 25 ug/L, and 2 to 27 ug/L, respectively. These volatile organic compounds were generally reduced to less than the method detection limit in all the SBR effluents for the duration of the study.

Tables 5-13, 5-14, and 5-15 present the results of analytical testing for base neutral extractables, acid extractables, and pesticides/PCBs, respectively. The one time analysis of base neutral and acid extractable organics and pesticides/PCBs indicate that these compounds were not detectable in either the raw or pretreated feeds nor were these compounds detectable in the effluents from the SBRs.

5.02.08 Activated Carbon Adsorption

Carbon adsorption isotherm testing employing PAC was substituted for granular activated carbon (GAC) column testing because column testing would have required an unavailable volume of low strength SBR effluent. PAC was obtained by pulverizing Calgon FS-400 GAC through a 200 mesh sieve (particle size less than 75 um). An adsorption isotherm was developed using effluent from Reactor A. Reactor A effluent was employed because it had not been enhanced with PAC and because it best represented the anticipated full scale treatment system.

Five dosages of PAC ranging from 0 to 200 mg/L were added to 200 ml of Reactor A treated ground water. Each container was vigorously mixed for 2 hours. The resulting supernatants were filtered through a 0.45 um filter and analyzed for TOC.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

MAY 03, 1989

COMPOUND (ug/l)	INFLUENT RAW	INFLUENT PRET'D	EFFLUENT REACTOR-A	EFFLUENT REACTOR-C	EFFLUENT REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	5	6	4J	4J	4J
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	U	31	U	U	U
1,1,1-Trichloroethane	U	U	2J	3J	2J
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	10	6	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	42	63	U	U	U
Chlorobenzene	25	11	U	U	U
Ethylbenzene	5	11	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

MAY 10, 1989

COMPOUND (ug/l)	INFLUENT RAW	INFLUENT PRET'D	EFFLUENT REACTOR-A	EFFLUENT REACTOR-C	EFFLUENT REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	4JB	4JB	7B	8B	7B
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	41	91	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	7	8	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	57	69	U	U	U
Chlorobenzene	17	14	U	U	U
Ethylbenzene	11	19	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

MAY 17, 1989

COMPOUND (ug/l)	INFLUENT RAW	INFLUENT PRET'D	EFFLUENT REACTOR-A	EFFLUENT REACTOR-C	EFFLUENT REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	4JB	4JB	2JB	3JB	2JB
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	24	66	U	U	3J
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	7	8	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	48	140	U	U	U
Chlorobenzene	14	13	U	U	U
Ethylbenzene	8	14	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

MAY 31, 1989

COMPOUND (ug/l)	INFLUENT		EFFLUENT		
	RAW	PRET'D	REACTOR-A	REACTOR-C	REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	3J	4J	5	5	5
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	22	7	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	6	6	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	42	22	U	U	U
Chlorobenzene	15	15	U	U	U
Ethylbenzene	27	9	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

JUNE 7, 1989

COMPOUND (ug/l)	INFLUENT		EFFLUENT		
	RAW	PRET'D	REACTOR-A	REACTOR-C	REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	U	3J	3J	U	3J
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	22	7	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	4J	U	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	12	9	U	U	U
Chlorobenzene	18	13	U	U	U
Ethylbenzene	3J	2J	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

JUNE 21, 1989

COMPOUND (ug/l)	INFLUENT		EFFLUENT		
	RAW	PRET'D	REACTOR-A	REACTOR-C	REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	U	8	U	U	U
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	U	U	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	3J	3J	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	28	110	U	U	U
Chlorobenzene	14	6	U	U	U
Ethylbenzene	2J	5	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

JUNE 28, 1989

COMPOUND (ug/l)	INFLUENT		EFFLUENT		
	RAW	PRET'D	REACTOR-A	REACTOR-C	REACTOR-D
Chloromethane	U	-	-	-	-
Bromomethane	U	-	-	-	-
Vinyl Chloride	U	-	-	-	-
Chloroethane	U	-	-	-	-
Methylene Chloride	3J	-	-	-	-
Trichlorofluoromethane	U	-	-	-	-
Acrolein	U	-	-	-	-
Acrylonitrile	U	-	-	-	-
1,1-Dichloroethene	U	-	-	-	-
1,1-Dichloroethane	U	-	-	-	-
1,2-Dichloroethene (total)	U	-	-	-	-
Chloroform	U	-	-	-	-
1,2-Dichloroethane	22	-	-	-	-
1,1,1-Trichloroethane	U	-	-	-	-
Carbon Tetrachloride	U	-	-	-	-
Bromodichloromethane	U	-	-	-	-
1,2-Dichloropropane	U	-	-	-	-
c-1,3-Dichloropropene	U	-	-	-	-
2-Chloroethylvinylether	U	-	-	-	-
Trichloroethene	9	-	-	-	-
Dirbromochloromethane	U	-	-	-	-
1,1,2-Trichloroethane	U	-	-	-	-
Benzene	3J	-	-	-	-
t-1,3-Dichloropropene	U	-	-	-	-
Bromoform	U	-	-	-	-
Tetrachloroethene	U	-	-	-	-
1,1,2,2-Tetrachloroethane	U	-	-	-	-
Toluene	34	-	-	-	-
Chlorobenzene	16	-	-	-	-
Ethylbenzene	2J	-	-	-	-

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-12

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - VOLATILE ORGANICS

JULY 6, 1989

COMPOUND (ug/l)	INFLUENT		EFFLUENT		
	RAW	PRET'D	REACTOR-A	REACTOR-C	REACTOR-D
Chloromethane	U	U	U	U	U
Bromomethane	U	U	U	U	U
Vinyl Chloride	U	U	U	U	U
Chloroethane	U	U	U	U	U
Methylene Chloride	U	U	U	U	U
Trichlorofluoromethane	U	U	U	U	U
Acrolein	U	U	U	U	U
Acrylonitrile	U	U	U	U	U
1,1-Dichloroethene	U	U	U	U	U
1,1-Dichloroethane	U	U	U	U	U
1,2-Dichloroethene (total)	U	U	U	U	U
Chloroform	U	U	U	U	U
1,2-Dichloroethane	U	U	U	U	U
1,1,1-Trichloroethane	U	U	U	U	U
Carbon Tetrachloride	U	U	U	U	U
Bromodichloromethane	U	U	U	U	U
1,2-Dichloropropane	U	U	U	U	U
c-1,3-Dichloropropene	U	U	U	U	U
2-Chloroethylvinylether	U	U	U	U	U
Trichloroethene	U	U	U	U	U
Dirbromochloromethane	U	U	U	U	U
1,1,2-Trichloroethane	U	U	U	U	U
Benzene	7	3J	U	U	U
t-1,3-Dichloropropene	U	U	U	U	U
Bromoform	U	U	U	U	U
Tetrachloroethene	U	U	U	U	U
1,1,2,2-Tetrachloroethane	U	U	U	U	U
Toluene	43	27	U	U	U
Chlorobenzene	25	11	U	U	U
Ethylbenzene	7	7	U	U	U

J - Detected but less than method detection limit.
U - Undetected.
B - Also detected in blank.

TABLE 5-13

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - BASE/NEUTRAL EXTRACTABLE ORGANICS

JUNE 1, 1989

COMPOUNDS	DETECTION LIMITS ug/l	INFLUENT RAW ug/l	INFLUENT PRET'D ug/l	EFFLUENT REACTOR A ug/l	EFFLUENT REACTOR C ug/l	EFFLUENT REACTOR D ug/l
N-Nitrosodimethylamine	10	U	U	U	U	U
Bis (2-chloroethyl) ether	10	U	U	U	U	U
1,3-Dichlorobenzene	10	U	U	U	U	U
1,4-Dichlorobenzene	10	U	3J	U	U	U
1,2-Dichlorobenzene	10	2J	2J	U	U	U
Bis (2-chloroisopropyl) ether	10	U	U	U	U	U
Hexachloroethane	10	U	U	U	U	U
N-Nitrosodi-n-propylamine	10	U	U	U	U	U
Nitrobenzene	10	U	U	U	U	U
Isophorone	10	U	U	U	U	U
Bis (2-chloroethoxy) methane	10	U	U	U	U	U
1,2,4-Trichlorobenzene	10	U	U	U	U	U
Naphthalene	10	5J	1J	U	U	U
Hexachlorobutadiene	10	U	U	U	U	U
Hexachlorocyclopentadiene	10	U	U	U	U	U
2-Chloronaphthalene	10	U	U	U	U	U
Dimethyl phthalate	10	U	U	U	U	U
Acenaphthalene	10	U	U	U	U	U
2,6-Dinitrotoluene	10	U	U	U	U	U
Acenaphthene	10	U	U	U	U	U
2,4-Dinitrotoluene	10	U	U	U	U	U
Diethylphthalate	10	2J	3J	U	1J	U
Fluorene	10	U	U	U	U	U
4-Chlorophenyl phenyl ether	10	U	U	U	U	U
4-Bromophenyl phenyl ether	10	U	U	U	U	U
N-nitrosodiphenylamine	10	U	U	U	U	U
Hexachlorobenzene	10	U	U	U	U	U
Phenanthrene	10	U	U	U	U	U
Anthracene	10	U	U	U	U	U
Di-n-butyl phthalate	10	0.3J	U	U	U	U
Fluoranthene	10	U	U	U	U	U
Benzidine	80	U	U	U	U	U
Pyrene	10	U	U	U	U	U
Butyl benzyl phthalate	10	U	U	U	U	U
3,3-Dichlorobenzidine	20	U	U	U	U	U
Chrysene	10	U	U	U	U	U
Benzo(a)anthracene	10	U	U	U	U	U
Bis (2-ethylhexyl) phthalate	10	2JB	240B	28B	34B	430B
Di-n-octylphthalate	10	U	U	U	U	U
Benzo(b)fluoranthene	10	U	U	U	U	U
Benzo(k)fluoranthene	10	U	U	U	U	U
Benzo(a)pyrene	10	U	U	U	U	U
Benzo(g,h,i)perylene	10	U	U	U	U	U
Dibenzo(a,h)anthracene	10	U	U	U	U	U
Indeno(1,2,3-cd)pyrene	10	U	U	U	U	U
1,2-diphenylhydrazine(2)	10	U	-	-	-	-

J - Detected but less than method detection limit.
U - Undetected.
B - Also detcted in blank.

TABLE 5-14

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS - ACID EXTRACTABLE ORGANICS

JUNE 1, 1989

COMPOUNDS	DETECTION LIMITS ug/l	INFLUENT RAW ug/l	INFLUENT PRET'D ug/l	EFFLUENT REACTOR A ug/l	EFFLUENT REACTOR C ug/l	EFFLUENT REACTOR D ug/l
phenol	10	U	U	U	U	U
2-chlorophenol	10	U	U	U	U	U
2-nitrophenol	10	U	U	U	U	U
2,4-dimethylphenol	10	U	U	U	U	U
2,4-dichlorophenol	10	U	U	U	U	U
4-chloro-3-methyl phenol	10	U	U	U	U	U
2,4,6-trichlorophenol	10	U	U	U	U	U
2,4-dinitrophenol	50	U	U	U	U	U
4-nitrophenol	50	U	U	U	U	U
2-methyl-4,6-dinitrophenol	50	U	U	U	U	U
pentachlorophenol	50	U	U	U	U	U

U - Undetected

TABLE 5-15

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

BENCH-SCALE BIOLOGICAL TESTING ANALYTICAL RESULTS
PESTICIDES/PCBs

COMPOUNDS	DETECTION LIMITS ug/l	RAW FEED ug/l	PRETREATED FEED ug/l
alpha BHC	0.01	U	U
beta BHC	0.01	U	U
gamma BHC	0.01	U	U
delta BHC	0.01	U	U
Heptachlor	0.01	U	U
Aldrin	0.01	U	U
4,4'DDE	0.01	U	U
Dieldrin	0.01	U	U
4,4'DDD	0.05	U	U
Endrin aldehyde	0.05	U	U
4,4'DDT	0.05	U	U
Chlordane	0.10	U	U
Endosulfan I	0.05	U	U
Endosulfan II	0.05	U	U
Endosulfan sulfate	0.05	U	U
Heptachlor epoxide	0.01	U	U
Toxaphene	1.00	U	U
PCB - 1016	0.20	U	U
PCB - 1221	0.20	U	U
PCB - 1232	0.20	U	U
PCB - 1242	0.20	U	U
PCB - 1248	0.20	U	U
PCB - 1254	0.20	U	U
PCB - 1260	0.20	U	U

U - Undetected

The PAC adsorption isotherm test results are presented in Table 5-16. Extrapolation of these results indicates that carbon adsorption is capable of reducing SBR effluent to TOC concentrations below effluent discharge limitations of 10 mg/L.

The average SBR effluent TOC concentration for all reactors over the course of the study was approximately 20 mg/L. The batch powdered activated carbon test results indicate that effluent TOC can be reduced to below effluent discharge limitations by carbon adsorption, given activated carbon dosages of 200 mg/l or greater.

5.02.09 Solids Handling

The Conceptual Design Report (1) indicated that the Parsippany-Troy Hills Wastewater Treatment Plant (WWTP) possessed excess solids handling capacity and might be willing to accept sludge generated from the ground water treatment facility. Sludge dewatering tests were to be conducted (per the Field Sampling and Testing Plan - November 1988) using a volume proportionate mixture of sludge from the Parsippany-Troy Hills Wastewater Treatment Plant (WWTP) and that generated during biological testing of Combe Fill South Landfill ground water. WWTP officials contacted by telephone indicated that they would not be interested in processing sludge generated by the full-scale Combe Fill South Landfill ground water treatment facility. WWTP officials did not cooperate in supplying sludge for testing. The sludge generated from the bench-scale SBRs was not sufficient to perform sludge dewaterability testing. Therefore, dewaterability of bench-

TABLE 5-16

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

PAC ADSORPTION ISOTHERM
TEST RESULTS

PAC (mg/l)	Final TOC (mg/l)
0	22.4
30	22.5
50	16.0
100	13.0
200	10.2

scale sludges was not tested and filter cake was not generated. Since a filter cake was not available, no sludge samples were tested for heavy metals or volatile organics.

It is proposed that primary sludge from metals pretreatment and waste activated sludge generated by the full-scale Combe Fill South Landfill ground water treatment facility will be dewatered on-site by pressure filtration. The full-scale system filter cake is not anticipated to be a characteristic hazardous waste.

Table 5-17 presents the recently promulgated toxicity characteristic maximum concentrations along with predicted maximum allowable ground water concentrations of toxicity characteristic substances based on expected ground water flow, daily filter cake mass, solids concentration and an assumed 100 percent transfer of contaminants in the ground water to the filter cake. The recently promulgated toxicity characteristic maximum concentrations are contained in the Federal Register dated March 29, 1990, pages 11798 to 11877. Each maximum allowable ground water concentration is a level which, if exceeded, would cause the filter cake to exceed the toxicity characteristic maximum concentration for that substance. With the exception of the highest observed concentrations of benzene and 1,2-dichloroethane, each predicted maximum allowable ground water concentration is greater than actual ground water characteristics, indicating that sludge produced would not be hazardous as defined by the TCLP test. Benzene and 1,2-dichloroethane concentrations should not render the filter cake hazardous by the toxicity characteristic since biological oxidation and volatilization of benzene in the biological treatment

TABLE 5-17
COMBE FILL SOUTH LANDFILL
MAXIMUM ALLOWABLE GROUND WATER CONCENTRATIONS

	Maximum Concentration of Contaminants for the Toxicity Characteristic (mg/l)	Allowable Headworks Loading Based on Prevention of Toxicity Characteristics (lbs/day)	Allowable Headworks Loading 175,000 gpd (ug/l)	Ground Water Characteristics* (1986 - 1988) (ug/l)	Ground Water Characteristics* (1989) (ug/l)
Arsenic	5.0	0.58	397.40	U - 88.7	U
Barium	100.0	11.60	7947.93	12.28 - 574	NA
Benzene	0.5	0.06	39.74	U - 80.2	3J - 10
Cadmium	1.0	0.12	79.48	U - 10.1	U
Carbon Tetrachloride	0.5	0.06	39.74	NA	U
Chlordane	0.03	0.003	2.38	NA	NA
Chlorobenzene	100.0	11.60	7947.93	U - 52	14 - 25
Chloroform	6.0	0.70	476.88	U - 57.5	U
Chromium	5.0	0.58	397.40	U - 30.1	25.8
o-Cresol	200.0	23.20	15895.85	NA	NA
m-Cresol	200.0	23.20	15895.85	NA	NA
p-Cresol	200.0	23.20	15895.85	NA	NA
Cresol	200.0	23.20	15895.85	NA	NA
2,4-D	10.0	1.16	794.79	NA	NA
1,4-Dichlorobenzene	7.5	0.87	596.09	U - 39.4	U
1,2-Dichloroethane	0.5	0.06	39.74	U - 6.1	U - 41
1,1-Dichloroethylene	0.7	0.08	55.64	U	U
2,4-Dinitrotoluene	0.13	0.02	10.33	NA	U
Endrin	0.02	0.002	1.59	NA	U
Heptachlor	0.008	0.001	0.64	NA	U
Hexachlorobenzene	3.0	0.35	238.44	NA	U
Hexachlorobutadiene	0.5	0.06	39.74	NA	U
Hexachloroethane	3.0	0.35	238.44	NA	U
Lead	5.0	0.58	397.40	U - 37.2	U - 5.5
Lindane	0.4	0.05	31.79	NA	NA
Mercury	0.2	0.02	15.90	U - 0.2	U
Methoxychlor	10.0	1.16	794.79	NA	NA
Methyl ethyl ketone	200.0	23.20	15895.85	NA	NA
Nitrobenzene	2.0	0.23	158.96	NA	U

TABLE 5-17
COMBE FILL SOUTH LANDFILL
MAXIMUM ALLOWABLE GROUND WATER CONCENTRATIONS

	Maximum Concentration of Contaminants for the Toxicity Characteristic (mg/l)	Allowable Headworks Loading Based on Prevention of Toxicity Characteristics (lbs/day)	175,000 gpd (ug/l)	Ground Water Characteristics* (1986 - 1988) (ug/l)	(1989) (ug/l)
Pentachlorophenol	100.0	11.60	7947.93	NA	U
Pyridine	5.0	0.58	397.40	NA	NA
Selenium	1.0	0.12	79.48	U - 5.0	U - 6.2
Silver	5.0	0.58	397.40	U - 10.0	U
Tetrachloroethylene	0.7	0.08	55.64	U - 4.1	NA
Toxaphene	0.5	0.06	39.74	NA	U
Trichloroethylene	0.5	0.06	47.96	U - 4.0	U
2,4-5-Trichlorophenol	400.0	46.40	38369.30	NA	NA
2,4,6-Trichlorophenol	2.0	0.23	191.85	NA	U
2,4,5-TP	1.0	0.12	95.92	NA	NA
Vinyl Chloride	0.2	0.02	19.18	U - 10.0	U

*From Tables 2-1, 2-2, 2-8, 2-11, 2-12, 2-13, 2-14, and 2-15
J - Detected but less than method limit
U - Undetected
B - Also detected in blank
NA - Not Analyzed

Calculation of Allowable headworks loading based on prevention of TCLP Toxicity:

$$\text{ALLOWABLE HEADWORKS LOADING (lbs/day)} = \frac{(V)(Chc)(Msl)}{(R)(M)(PS)}$$

V = Volume of liquid in test (2 liters)
Chc = Concentration of contaminant for TCLP hazardous classification (mg/l)
Msl = Mass of sludge generated (1740 lbs/day)
R = Removal in treatment plant (Conservative estimate = 100 percent/100)
M = Mass of sample in test (100,000 milligrams)
PS = Concentration of sludge solids (30 percent/100)

system will yield a very low mass transfer efficiency from the ground water to the sludge.

5.02.10 Effluent Toxicity Testing

Both acute and chronic toxicity testing was conducted on fish and invertebrates using effluent from treatability testing Alternate C. This effluent was Combe Fill South Landfill shallow ground water which had been pretreated for metals by chemical coprecipitation and treated by a PAC enhanced biological suspended growth sequencing batch reactor.

Toxicity testing consisted of 96 hour static renewal bioassays employing both fathead minnows (Pimephales promelas) and Daphnia magna. Acute toxicity testing was conducted by O'Brien & Gere Engineers, Inc. in its Syracuse, New York toxicity testing facilities. Concentrations of treated effluent varying from 100 to 0 percent were prepared using dilution water obtained from just downstream of the confluence of the east and west branches of Trout Brook. This location was identified by NJDEP as the expected discharge point of the ground water treatment facility, and, as such, represented the receiving water to be utilized in the test method. The percent mortality of the two biological indicators was recorded after 96 hours and the corresponding LC-50s were calculated. Test conditions are detailed in Appendix 5-1.

The results of the acute toxicity testing performed on the effluent from the bench-scale SBRs are presented in Table 5-18. Based upon the 15 percent mortality demonstrated in 100 percent of the sample, the LC-50s for the treated ground water are greater than 100 percent for both the vertebrate (fathead minnows) and the invertebrate (Daphnia magna) species. It is possible, but has not been confirmed, that the dilution water obtained from Trout Brook is toxic to the Daphnia magna as indicated by the 100 percent mortality produced by concentrations of dilution water exceeding 75 percent. Because the dilution water was toxic, the control mortality was in excess of 10 percent which is outside NJDEP control limits for the test.

Although the bioassay did not meet the QA/QC acceptance criteria due to the toxic dilution water (receiving stream), the test was properly conducted and provided data useful to the project. These data indicate that the effluent from the proposed ground water treatment facility should not pose a significant environmental hazard upon discharge to Trout Brook.

Chronic toxicity testing performed on the effluent from the bench-scale SBRs was performed in accordance with the NJDEP interim chronic toxicity testing methodology. Chronic toxicity testing was performed by International Technology Corp. of Edison, New Jersey. The chronic testing was accomplished utilizing short-term tests on fathead minnows (Pimephales promelas) and water fleas (Ceriodaphnia dubia). The results of the chronic tests demonstrate the effluent to be of low chronic toxicity (Appendix 5-2). In both the fathead minnow and Ceriodaphnia tests, measurable effects were observed in the 100 percent effluent samples only, with no effects measured at subsequent dilutions. In the fathead minnows, the only effect observed was mortality, with a calculated LC_{50} of 92.9 percent of effluent. The Ceriodaphnia test did not show measurable toxicity, but demonstrated

TABLE 5-18

COMBE FILL SOUTH LANDFILL
GROUND WATER TREATABILITY STUDY

96-HOUR ACUTE BIOASSAY TEST RESULTS *

Effluent Conc. (%)	Percent Survival	
	Fathead Minnows	Daphnia Magna
100	85	85
50	75	90
25	75	95
12.5	75	0
6.25	90	0
0	80	0

* Effluent produced from treatment alternative C involving metals pretreatment followed by PAC enhanced SBR biological treatment of ground water. Effluent diluted with water obtained from Trout Brook, the proposed receiving water.

reproductive effects in two 100 percent effluent samples only. The results of these tests suggest that, following minimal dilution, the effluent discharged would not be expected to cause adverse aquatic impacts.

5.02.11 Recommended Treatment System

The treatability study was formulated to assess the efficacy and efficiency of the four different treatment alternatives presented in Figure 5-1. The alternatives were constructed based upon ground water quality data generated during the RI and the IEMP, and address the treatment of the different contaminants found at the site including heavy metals, volatile organic substances, and BOD5.

Ground water obtained for the treatability study contained lower concentrations of BOD5, TSS, VOCs, and heavy metals, than had been expected based upon previous studies conducted at the site. All the alternatives performed comparably in removing ground water contaminants. Heavy metals were effectively removed and tolerated in biological systems, whether or not the raw ground water was pretreated for metals by chemical co-precipitation. Volatile organics were eliminated from the ground water in all SBR reactor configurations including the one without PAC. BOD5 removals were consistent between the different treatment scenarios indicating that neither heavy metal nor other contaminant toxicity posed an operational problem for the biological systems.

In light of the temporal variability in ground water quality and the unknown quality of landfill gas condensate requiring treatment, a high degree of conservatism is required in the design of the ground water treatment system. Hence, Treatment Alternative A (Figure 5-1) which includes metals pretreatment, biological treatment with SBRs, filtration, and GAC adsorption polishing has been selected as the treatment strategy. Further, it is recommended that PAC dosage capabilities be provided for the SBRs.

The selected treatment strategy (Treatment Alternative A) incorporates processes designed to enhance the system's ability to consistently meet all discharge limits. Specifically, unit processes including sand filters and GAC adsorption units are included to minimize the possibility of effluent excursions. The SBR design was chosen over other biological treatment system configurations because it is relatively easy to operate and offers more operational flexibility than other designs such as continuous flow activated sludge. Operational flexibility is critical considering the long-term changes in ground water quality and quantity anticipated. During the treatability study pretreatment was not a significant factor in the removal of heavy metals from ground water. However, due to the expected long-term variability in ground water quality and the history of ground water heavy metals contamination at the site, metals pretreatment has been included in the design of the treatment system.

Landfill gas condensate (LGC) is expected to be a component of liquids requiring treatment at the Combe Fill South Landfill. Therefore, a 15,000 gallon condensate equalization tank equipped with a mixer and skimmer will be employed for pretreatment of the LGC. The condensate will be equalized in this tank prior to discharge to the downstream SBRs. The

SBRs are not expected to accommodate 5,000 gpd of typical strength LGC (per the literature; Table 5-5). The condensate equalization tank will, therefore, be equipped with fittings to allow for pumping of condensate to a tanker truck for transport to an off-site disposal facility, if required.

The processes included for ground water treatment include flow equalization, heavy metals co-precipitation, biological treatment in SBRs, filtration of SBR effluent, GAC adsorption polishing and gravity discharge to Trout Brook. Facilities will be provided to allow the introduction of PAC to the SBRs, in the event that variations in ground water and LCG quality warrant supplemental PAC addition. Additionally, facilities will be provided to allow nitrogen and phosphorus additions in the event of nutrient deficiencies. Table 5-19 indicates the rationale for selection of each process.

Table 5-20 contains the flow and mass balance for the different unit processes proposed for the treatment of ground water and condensate at the Combe Fill South Landfill. This treatment strategy should be able to meet the heavy metals, VOC, BOD5 and all other effluent discharge limitations proposed for the treatment facility.

The mass balance contained in Table 5-20 and ultimately the preliminary design assumes the following:

1) Ground water flow and gas condensate flow are projected to be 170,000 and 5,000 gpd, respectively.
2) Ground water strength is comparable to that reported in the RI
3) Landfill gas condensate quality is based on the one sample characterized.

TABLE 5-19

COMBE FILL SOUTH LANDFILL

RECOMMENDED TREATMENT SYSTEM

Unit Operation	Rationale For Selection
Landfill Gas Condensate Aerated Equalization	Dampens effects on downstream process system resulting from variations in landfill condensate loadings and flow. Provides a location for segregation and alternative handling (e.g. transport and off-site treatment).
Influent Flow Equalization	Dampens effects on downstream process system resulting from variations in loadings and flow. Provides short-term emergency storage. Allows for batch operation (one shift) of the entire treatment facility as flows reduce over time.
Metals Removal System	Provides for removal of heavy metals and other particulates.
Biological Treatment with SBRs	Provides for removal of organics (BOD_5, TOC, volatile organics and phenolics), and ammonia. Selected for effluent quality achievable, operational flexibility and low operator attention. Operational flexibility is considered critical considering the long-term changes in ground water quality and quantity anticipated.
Optional PAC Enhancement of SBRs	Provides enhanced flexibility for treatment of high-strength ground water or leachate.
Filtration	Provides for removal of suspended solids to assure compliance with effluent limitations and to prolong carbon adsorption bed life.
Carbon Adsorption	Provides for removal of trace organics to a level consistent with discharge objectives.
Sludge Dewatering	Achieves acceptable and cost effective solids content prior to off-site disposal.

TABLE 5-20

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE REMEDIAL DESIGN
GW/CONDENSATE TREATMENT
BASIS OF DESIGN MASS BALANCE

Key to Mass Balance Locations

1 - Equalized Condensate

2 - Raw GW
3 - Equalized GW
4 - SBR Feed
5 - Primary Sludge

6 - SBR Effluent
7 - SBRs WAS

8 - Filter Effluent
9 - Filter Backwash

10 - GAC Columns Effluent
11 - GAC Backwash
12 - Spent Carbon

13 - GW WAS, and GW PS
14 - Filter Backwash, Backwash and Filtrate to GW Equalization Tank
15 - Filter Cake

TABLE 5-20

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE REMEDIAL DESIGN
GW/CONDENSATE TREATMENT
BASIS OF DESIGN MASS BALANCE

	FLOW (gpd)	COD (lb/d)	BOD5 (lb/d)	NH3 (lb/d)	TSS (lb/d)	METALS (lb/d)
1	5000	160	80	2	0.5	0.008
2	170000	290	145	75	680	1.2
3	188000	290	145	75	830	1.2
4	184000	450	225	77	10	0.1
5	9000				1150	
6	182000	150	20	6	5	0.08
7	2300				50	
8	175000	120	18	5	2	0.07
9	7200				3	
10	175000	24	6	0.75	1	0.05
11	TBD					
12	365000**					
13	11300				1740	
14	18200				150	
15	****					

* - See next page for key to mass balance locations
** - lb GAC/yr; may range from 50000 to 500000 lb/yr, depending upon efficiency of upstream processes and whether PAC is used in central SBRs
*** - includes 0.5 lb $Ca(OH)_2$ per lb solids
**** - 90 cubic feet per day (7,200 lbs per day wet sludge)
TBD - to be determined

4) Sludge generated from metals precipitation and SBRs will be thickened and subsequently processed through a filter press and disposed off-site.

5) The sludge pressure filter filtrate and sand filter backwash, and GAC backwash will be routed to the head of the plant.

6) Landfill gas condensate will be contained in an aerated equalization tank and combined with the ground water prior to treatment with SBRs.

5.02.12 Treatability Study References

1. Lawler, Matusky, and Skelly Engineers. 1987. "Final Conceptual Design Report Remedial Investigation/ Feasibility Study Combe Fill South Landfill."

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3. Lofy, Ronald J. "Landfill Gas Condensate and Its Disposal" presented at University of Wisconsin. Extension Course, Sanitary Landfill Gas and Leachate Management, 1985.

4. SCS Engineers, Inc., "Municipal Landfill Gas Condensate" EPA-600/2-87/090.

5. Meidel, J.A. and R.L. Peterson. 1987. "The Treatment of Contaminated Ground Water and RCRA Wastewater at Bofors-Nobel, Inc." Fourth National RCRA Conference on Hazardous Waste and Hazardous Materials (HMCRI). Washington D.C.. March 16-18.

6. Meidel, J.A. and Vollstedt, T.J. 1986. "Use of Powdered Carbon to Treat Contaminated Ground Water and Leachate" Haz Tech International Conference, Denver, CO. August 13, 1986.

7. Ying, W., R. Bonk, and S. Sojka. 1987. "Treatment of Landfill Leachate in Powdered Activated Carbon Enhanced Sequencing Batch Bioreactors." Environmental Progress. February, 1987.

5.03 Ground Water Treatment System Design

5.03.01 Design Criteria

Based upon the results of the laboratory treatability studies described in the previous section and based on accepted practices of environmental engineering design, a treatment system has been selected for treatment of ground water and condensate to be generated at the Combe Fill South Landfill. The treatment technology selected is a combination of physical, chemical and biological treatment designed to remove the identified constituents in the ground water and condensate. The selected technology dictates the required equipment such as treatment tankage, mixing devices, clarification units, filters, biological units and sludge dewatering equipment. The basis of design of the treatment system components was developed based on the process evaluations and testing performed, projected flow rates, and the established criteria for the treatment system.

This section of the report outlines the design criteria evaluated, the process description for the treatment facilities and a brief review of the permitting requirements associated with ground water/condensate treatment.

In the process of developing the basis of design for the ground water treatment facility, several major considerations have been included in the system selection and engineering process. These considerations include:

- The variability in anticipated influent flow and loadings likely to be encountered over the life of the treatment facility.

- The high degree of system reliability required due to the nature of the project and the need to consistently meet discharge limitations under variable conditions.
- A design that will accommodate drastic reductions in flow over time.
- A facility that can reasonably be expected to operate successfully without full time around the clock operator attendance.
- A degree of built in redundancy and fail safe concepts that result in a high degree of reliability in a reasonably cost effective manner.

These considerations along, with data collected at the site, treatability testing results and engineering judgements, form the basis of the design concepts described herein. Specific basis of design criteria include the following major items.

Flow

The design flow for the ground water treatment facility is based on two flow sources: landfill gas condensate (LGC) and recovered shallow ground water. The volume of LGC is estimated to be approximately 6000 gpd (max.) based on literature values and as high as 5400 gpd based on thermodynamic properties. In light of the reported literature values and recognition that the exact conditions which will be present when the gas extraction system is put into operation are not well defined, a conservative design flow rate of 5000 gpd (max.) of LGC has been selected for the design basis.

The volume of ground water currently flowing out of the landfill is estimated to be approximately 170,000 gpd. Placement of the landfill cap and cover is expected to reduce this flow volume over time. The reduction is calculated to be approximately 50 percent within two years of cap and cover completion and 90 percent within 10 years.

Based on present estimates, the ground water recovery wells will be capable of pumping approximately 280,000 gpd at the time of installation.

The proposed construction schedule includes a 36 month duration of construction. The ground water collection and treatment system is scheduled to be completed at approximately the mid point of construction (month 18) and the landfill cap and cover be installed between month 15 & 36.

As the landfill cap and cover will be partially in place over the final 20 months of construction, it is estimated that the volume of ground water discharge from the landfill will be substantially reduced. Further reductions will occur if the ground water treatment plant is in operation during the last 18 months of the project. The combined effect serves to reduce the estimated ground water discharge volume to approximately 140,000 gpd. The selected design capacity of the ground water treatment plant is based on this daily volume plus a 20 percent reserve for a total average daily design capacity of 170,000 gpd. Adding the 5000 gpd estimated LGC volume results in a total design capacity of 175,000 gpd. The 20 percent reserve capacity is thought to be conservative to provide flexibility to accommodate actual field conditions once ground water pumping operations begin and quality and quantity characteristics are known.

Loadings

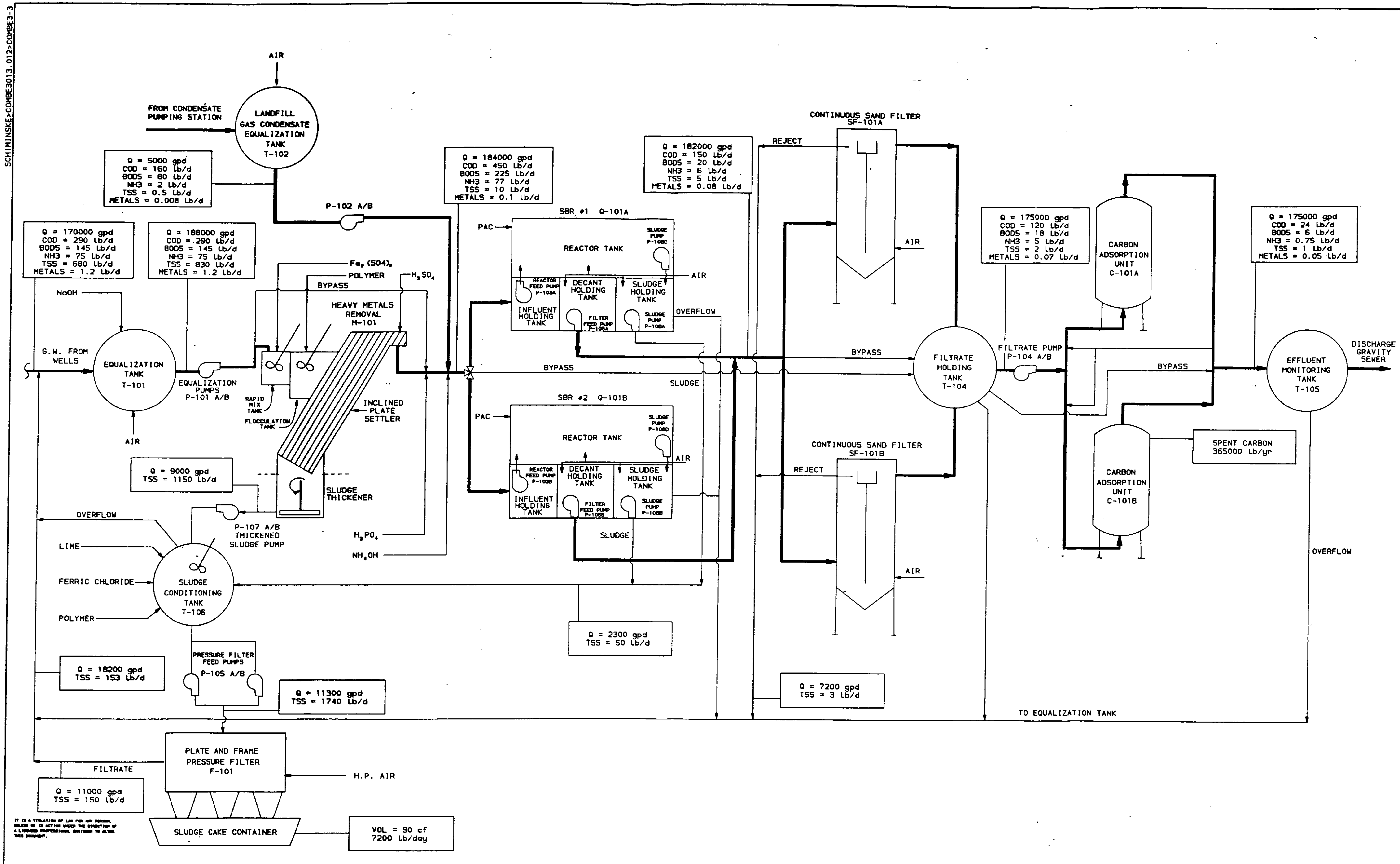
Organic and inorganic contaminants in the ground water were measured from shallow well samples within the landfill area and appear in Table 5-1. From the measured values, expected average influent characteristics were developed (Table 5-2). A single sample of LGC was obtained and contaminant levels analyzed (Table 5-6). Additionally, LGC characteristics were obtained from reported literature (Table 5-7). The combined ground water and LGC characteristics were used for the design basis of the ground water treatment facility. These loadings appear in Figure 5-5.

Treatment Processes

The recommendations of the treatability studies form the design basis for the proposed ground water treatment facility as outlined in Section 5.02.11. The recommended facility includes the following major unit processes:

- flow equalization (ground water)
- flow equalization (LGC)
- heavy metals removed via co-precipitation with ferric sulfate
- pH adjustment
- biological treatment
- filtration
- granular activated carbon (GAC) adsorption

As no source was identified locally to which liquid sludges could be shipped, it is recommended that on-site sludge dewatering be provided.



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O'BRIEN & GERE ENGINEERS, INC. Syracuse, New York

COMBE FILL SOUTH LANDFILL SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION

GENERAL
COMBE FILL SOUTH
PROCESS MASS BALANCE

FILE NO. 3013.012

DATE MAY, 1990

FIG. 5-5

Sludge handling for this project is proposed to include the following unit processes:

- aerated sludge holding tank(s) for biological sludges with provisions for decanting
- gravity sludge thickening for metal hydroxide sludge
- sludge conditioning with polymer, ferric chloride and lime or diatomaceous
- sludge dewatering via recessed plate and frame filter press
- shipment off-site of dewatered sludge cake for disposal.

5.03.02 Process Description/Basis of Design

The purpose of this section is to describe the unit processes which constitute the ground water/LGC treatment system. A description of the process flow scheme is provided as well as the major design parameters of the various treatment system components. Table 5-21 provides equipment descriptions and sizing criteria.

A description and narrative discussion is provided herein for each major unit process.

Flow Equalization

Flow equalization is proposed to accomplish the following five functions:

1) dampen hydraulic effects on downstream process systems resulting from flow volume variations,

TABLE 5-21

COMBE FILL SOUTH LANDFILL

GROUND WATER TREATMENT FACILITY

MAJOR PROCESS EQUIPMENT BASIS OF DESIGN

Process Equipment Designation	Equipment Description	Equipment Sizing Criteria
Ground Water Flow Equalization Tank T-101	Circular above grade, open top, welded steel tank, aerated 87,500 gal.	12 hrs. detention @ design flow rate (175,000 gpd) with 2' freeboard, 34' dia., 15' high, aerated to mix NAOH & suspend solids
LGC Equalization Tank T-102	Circular above grade, open top welded steel tank 15,000 gal.	5 days detention @ 5,000 gpd (max. with 2' freeboard, 18' dia. x 15' high
Ground Water Equalization Pumps P-101 A/B	(2) horizontal centrifugal, 120 gpm, 3 hp, variable speed (100% standby)	Peak design flow rate = 170,000 gpd ÷ 1440 min/day = 120 gpm + 15% reserve = 140 gpm (max. capacity each pump)
Condensate Equalization Pumps P-102 A/B	(2) horizontal centrifugal, 10 gpm (max) 1/2 hp, variable speed (100% standby)	Peak design condensate flow = 5000 gpd ÷ 1440 min/day = 3.5 gpm
Metals Removal System M-101	(1) Skid mounted package with inclined plate settler with rapid mix tank (100 gal) flocculation tank (500 gal) gravity sludge thickener (2,000 gal) with scraper mechanism	1 min. rapid mix tank detection @ 120 gpm = 120 gal 5 min. flocculation tank detention @ 120 gpm = 600 gal 0.3-0.6 gpm/sf clarifier loading, @ 170,000 gpd with 300 sf inclined, settler, loading rate = 0.40 gpm/sf call (all criteria based on vendor recommendation)
Sodium Hydroxide (NaOH) Feed System T-103, P-111 A/B	4,500 gal FRP storage tank, 8' dia. x 12' high (2) diaphragm metering pumps 5 gph max. rate, variable speed, pH control	With 50% NaOH sol, 0.55 gal. NaOH required/1,000 gal $0.55 \times \frac{175,000}{1,000} = 100$ gal. NaOH/day Provide 45 day storage capacity = 4,500 gal. tank Meter pump rate 100 gpd ÷ 24 hours/day = 4.2 gph
Ferric Sulfate Feed System T-107, P-112 A/B	1000 gal. solution batch mix tank, HDPE with bag breaker feeder, (2) diaphragm metering pumps 20 gphr max. rate, variable speed, flow proportional	Dose 100 mg/l as Fe (treatability report) Fe required = .175 MGD x 8.34 x 100 mg/L = 145 lbs/day Ferricfloc, 70 lb/CF, 18.5% Fe = 13 lb Fe/CF 11 CF/day @ 70 lbs/CF = 780 lb Ferricfloc/day Batch @ 2 lbs. Ferrifloc/gal = 400 gal batch/day Pump max. rate 400 gpd ÷ 24 hrs/day = 16.7 gph
Polymer Feed Systems P-113, P-118	Emulsion polymer feed unit with metering pump and controls	Dose 0.25 mg/l (treatability report) use 0.5 mg/l - metals ppt. Dose 200 mg/l - sludge conditions. Feed rate 0.5 mg/l = .175 mgd x 8.34 x 0.5 mg/l = 0.7 lb/day

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COMBE FILL SOUTH LANDFILL

GROUND WATER TREATMENT FACILITY

MAJOR PROCESS EQUIPMENT BASIS OF DESIGN
(Continued)

Process Equipment Designation	Equipment Description	Equipment Sizing Criteria
Sequencing Batch Reactors Q-101A/B	(2) Modular, above grade steel tank with 4 Internal compartments: - Influent holding - SBR reactor - decant holding - sludge holding	2 SBR units nominal rated @ 87,500 gpd each operating @ 2-12 hour cycles (from treatability report) Influent holding tank - 12 hours detention with 20% reserve @ 87,500 gpd = 43,750 gal ÷ 20% = 52,500 gal capacity Reactor tank, 200 lbs BOD ÷ 0.1 lb BOD/lb MLSS = 2,000 lb MLSS 2000 lbs MLSS ÷ (2500 mg/L x 8.34) = 0.095 MGal, say 100,000 gal ÷ 2 tanks = 50,000 gal capacity/tank Decant holding tank, 12 hours detention = 43,750 gal Sludge holding tank, 2,300 gpd waste sludge with 15 days detention = 35,000 gal
SBR Feed Pumps P-103 A/B	(3) Submersible (uninstalled spare) 750 gpm, 5 hp, variable speed drive	SBR feed rate, 43,750 gal in 1 hour (treatability report) 43,750 gal/60 min. = 730 gpm max. rate each pump
SBR Aeration Blowers B-101 A/B/C	(3) Positive displacement, 15 hp, 280 scfm @ 7.5 psi (50% standby)	200 lbs BOD/day x 2000 CF air/lb = 380,000 C Fair ÷ 1440 min/day = 280 scfm
Filter Feed Pumps P-106-A/B	(2) Submersible (uninstalled spare) 120 gpm 2.5 hp, variable speed drive	Peak flow = 175,000 gpd ÷ 1,440 min/day = 120 gpm ÷ 15% reserve = 140 gpm (max. capacity each pump)
Sand Filter SF-101 A/B	(2) Continuous backwash, upflow, deep bed granular media, 5 dia. x 12-6" high, 19 sf filtration area	4-8 gpm/sf loading rate @ 100 mg/l TSS (max) (vendor recommendation) Loading rate with two filters in operation = 65 gpm each ÷ 19 sf/filter = 3.4 gpm/sf
Filtrate Holding Tank T-104	(1) Circular, flat bottom, open top FRP, 1,800 gal, 6' dia x 9' high	15 min. detention @ 120 gpm = 1,800 gal
Filtrate Pumps P-104 A/B	(2) Horizontal centrifugal 140 gpm, 3 hp, variable speed drive	Peak flow = 175,000 ÷ 1440 = 120 gpm ÷ 15% reserve ÷ 140 gpm
Carbon Adsorption Units C-101 A/B	(2) 20,000 lb carbon capacity carbon vessels, skid mounted, pre-piped, down flow, fixed with 20,000 #spent carbon transfer tank (10' dia.)	Sized for 20,000 truck load delivery
Effluent Monitoring Tank T-105	(1) Circular, flat bottom, open top, FRP 600 gal, 4' dia. x 7'-0" high	5 min. detention @ 120 gpm = 600 gal
Sludge Conditioning Tank T-106	(1) Circular, flat bottom, open top, FRP, 6500 gal, 10' dia. x 10' high	Sized for one filter press batch, see filter press

COMBE FILL SOUTH LANDFILL

GROUND WATER TREATMENT FACILITY

MAJOR PROCESS EQUIPMENT BASIS OF DESIGN
(Continued)

Process Equipment Designation	Equipment Description	Equipment Sizing Criteria
Filter Press Feed Pumps P-105 A/B	(2) Air operated diaphragm 30 gpm	5500 gal/press cycled, 3 hour cycle, $\frac{5500\text{ gal}}{180\text{ min}} = 30$ gpm
Plate & Frame Filter Press F-101	(1) Recessed plate & frame with 39 cf press volume, 40" x 40" plates	1750 lbs. dry solid/day @ 1.8% solids, 11,700 gpd x 7/5 = 16,400 gpd (5 days/wk) Filter press vol. (ft^3) = $\frac{\text{gal/cycle} \times \%\text{ sludge conc.} \times 8.34 \times 5.6}{\text{cake density (lbs/CF)} \times \text{cake \% solids}}$ $= \frac{5{,}500\text{ gal} \times 0.018 \times 8.34 \times 1.07}{80\text{ lbs/CF} \times 0.30}$ = 37 CF (assumes three cycles/day)
Phosphoric Acid (Nutrient) Feed Pump P-116	(1) Metering pump from 55 gal drum, variable speed, manual control	BOD5: P = 100:1
Ammonium Hydroxide (Nutrient) Feed Pump P-115	(1) Metering pump from 55 gal. drum, variable speed, manual control	BOD5: N = 20:1
Sulfuric Acid Feed (pH adjust) Feed Pump P-114	(1) Metering pump from 55 gal. drum, variable speed, pH controller	pH decrease 8.5 to 7.0 S.U.

2) provide short term emergency storage,

3) dampen loading effects on downstream process system resulting from loading variations,

4) allow for one shift operation of the treatment facility as flows reduce over time, and

5) provide mixing of ground water with sodium hydroxide for pH adjustment prior to the metals removal step.

The proposed layout includes two above grade circular steel equalization tanks with a capacity of approximately 87,500 gallons and 15,000 gallons for ground water and LGC, respectively. The ground water flow equalization tank will be provided with a diffused aeration system to provide mixing and to suspend solids. A 87,500 gallon volume was selected for this tank to provide 12 hours detention at the design flow rate.

The ground water flow equalization tank will be provided with air diffusers to provide mixing, suspend solids, strip volatiles and prevent septicity of organic compounds. This tank will serve as a pH adjustment tank to facilitate the downstream metals removal step. Sodium hydroxide and ferric sulfate solutions will be metered into the ground water flow equalization tank on a pH controlled and flow proportional basis, respectively.

The LGC flow equalization tank will be provided with a submersible mixer and floating skimmer. The skimmer will remove the organic layer from the condensate surface and discharge into a storage drum. The effluent of the LGC flow equalization tank will be pumped by a variable speed, setpoint controlled pump to a point upstream of the SBRs. The ground water flow equalization tank effluent will be pumped by a variable speed, setpoint controlled pump to the downstream metals removal process. Both pumps will be provided with 100 percent standby capacity.

Both tanks will be fitted with level indicators, high level alarms, overflows from one tank to the other and tank fittings to allow pump out to a tanker truck.

Metals Removal

Based on the treatability testing results and recommendations in Section 5.02.06, chemical co-precipitation and clarification is proposed upstream of biological treatment. Metals removal via metal hydroxide precipitation with ferric sulfate aided by polyelectrolyte was demonstrated to meet objectives in the treatability evaluation.

The system proposed for this project consists of a skid mounted inclined plate settler unit with integral rapid mixing tank and flocculation tank. Additionally, an integrally mounted sludge thickener is provided beneath the inclined plate settler unit. Systems of this type are commonly applied for this purpose and are used extensively in industry.

As flow equalization is provided upstream, a continuous flow through unit is proposed and is available as a packaged unit in the desired size range. Clarification by inclined plate vs. traditional gravity clarifiers has proved successful for metal hydroxide sludges and is preferred since less space is required for the clarification unit and the system requires less mechanical components. The proposed metals removal unit contains no moving parts other than a simple mixer and flocculator, thus it is felt that maintenance requirements will be minimal and redundancy will not be necessary. Packaged inclined plate settler units are available with an integral sludge thickener tank mounted beneath the settler tank. This feature is proposed to eliminate the need for piping sludge to a remote tank and, therefore, reducing operational labor.

The sizing of the rapid mix/flocculation/inclined plate settler unit is based on the hydraulic flow rate. A typical loading rate for a metal hydroxide sludge is 0.3 to 0.6 gpm/sf based on a unit with inclined plates set at a 55° angle to the horizontal and the surface area based on 80 percent of the projected horizontal surface area. For this project, a 360 sf projected surface area unit is proposed, which at an initial design flow of 188,000 gpd (design flow and recycle streams) would provide a loading rate of 0.43 gpm/sf. The integral rapid mix and flocculation tanks are provided with 1 minute (120 gal) and 5 minutes detention time (650 gal).

The integral sludge thickener is mounted beneath the inclined plate settler and is provided with a mechanical sludge scraper mechanism. This arrangement allows solids which settle in the inclined plate settler to pass directly to the thickener tank. The thickener provides the function of reducing the sludge volume by increasing the percent solids and provides for storage of sludge solids between operation of the sludge dewatering system.

Equipment ancillary to the inclined plate settler will include a feed systems for sodium hydroxide, ferric sulfate and polymer and thickened sludge pumps.

Biological Treatment

The organic strength of the ground water has been characterized as shown in Table 5-2 This loading, combined with the loading of the LGC, forms the design organic loading of the biological treatment process.

Biological treatability testing was conducted utilizing a sequencing batch reactor (SBR) process. The SBR process can be described as a fill and draw, cyclic batch treatment type activated sludge process in which the SBR tank is filled with wastewater during a selected time period followed by selected time periods of aeration, settling, decanting and idle after which the cycle is repeated. This cyclic process coupled with a programmable logic controller provides an extremely flexible system which is not possible in a continuous flow biological process. By varying the operating strategy, aerobic, anaerobic, or anoxic conditions may be achieved allowing for development of desirable microorganisms while the growth of undesirable microorganisms is inhibited. This operating flexibility is well suited to the ground water flow and loading variations likely to be encountered on this project. Additionally, the treatability testing was conducted utilizing an SBR.

Physically, the biological treatment process for this project is proposed to include two SBR tanks each with a nominal design capacity of 87,500 gpd. Each SBR tank is proposed to be a circular above grade steel tank with four internal compartments (Drawing M-4). The internal compartments would include: influent holding tank, SBR reactor tank, decant holding tank and sludge holding tank. All tanks would be aerated with diffused air. The influent holding tank is provided to retain influent flows between SBR cycles and the decant holding tank is provided to equalize decant flows prior to filtration. Other major components of the system will include:

- SBR feed pumps to transfer wastewater from the influent holding compartment to the SBR reactor.
- Diffused aeration system for mixing and aerating all four compartments.
- SBR decanter mechanism.
- Aeration blowers.
- Powered Activated Carbon (PAC) addition system.
- Sludge wasting pump.
- Nutrient feed system including storage tank and flow proportional metering pumps for phosphoric acid and ammonium hydroxide.
- programmable logic controller.

Two SBR tanks are proposed which, at start-up, would be nominally capable of processing 50 percent of the design flow (75,000 gpd ground water and 12,500 gpd internal recycles). After approximately two years of operation, when average daily flows are projected to have decreased to approximately 75,000 gpd, 100% standby redundancy of the SBR tanks would exist and in the normal operation mode, only one SBR tank would be in service.

An F/M ratio of approximately 0.1 lbs BOD/lb MLVSS is recommended for the full-scale treatment system and is typical of extended aeration treatment processes. At an F/M ratio of 0.1, microorganisms will operate in the endogenous respiration mode. This will limit the quantity of biological sludge requiring dewatering and disposal.

As discussed in Section 5.02.11, powered activated carbon (PAC) addition to the SBR reactor is recommended. Physical facilities to add PAC include a dustless debagging station, carbon slurry mix tank, mixer, feed pumps, piping and valves. A royalty must be paid to a private licensor when the PAC system is placed into service.

Filtration

To consistently meet the objectives of effluent suspended solids and to prevent blinding of the downstream carbon adsorption units, filtration of biological treatment process effluent is proposed. Two 5-foot diameter x 12'-6" high upflow sand filters are proposed. This type of pressure filtration unit is recommended due to the continuous nature of operation.

Traditional filters (either gravity or pressure) are taken out of service for backwashing for removal of solids from the filter media. The water necessary for backwash and the resultant backwash waste require inclusion of holding tanks along with pumps, automated valves and controls. The continuous backwash filter requires only the filter units and a compressed air source for operation. Additionally the filter vendors advise that rate of flow controllers are not required for this type of filter.

This type of filter has been successfully applied in numerous industrial waste treatment applications, both in biological waste treatment systems and physical/chemical treatment systems.

Application rates for the filters are approximately 4-8 gpm/SF for biological solids with loadings up to 20 mg/L. Two 19 SF filters will be provided with the design flow rate of 130 gpm being split between them, for a 65 gpm loading on each filter. The resulting loading rate is 3.4 gpm/SF.

Equipment ancillary to the sand filters include an air compressor and a filter feed pump. The filter contains no moving parts and generally requires little operator attention or maintenance.

Carbon Adsorption

Consistent and high level removals of trace organics to a level consistent with discharge objectives requires polishing by carbon adsorption. Carbon adsorption should act as a failsafe system to prevent discharge of organics should the upstream biological treatment units experience an upset.

A dual module, skid mounted, package carbon adsorption unit is proposed. The unit is pre-piped to allow for flow through the vessels in series or parallel modes of operation, and is also backwashable. It would include two (2) 10 ft diameter carbon steel vessels each holding 20,000 pounds of carbon. As a delivery truck load of carbon is 20,000 pounds, this vessel sizing is proposed to maximize the economics of bulk carbon purchases. At a flow rate of 100 gpm, each absorber provides approximately 50 minutes of contact time.

Equipment ancillary to the carbon absorber units include a carbon transfer tank, carbon backwash pump and compressed air source is necessary for carbon transfer during changeout.

Carbon Backwash Tank

Effluent from the carbon adsorber units is proposed to discharge either to a 22,000 gallon exterior welded steel storage tank or directly to the plant outfall. The tank would serve as a reservoir of plant effluent used to backwash the carbon adsorption vessels. A cascade at the end of the plant outfall will provide post aeration capability. Cascade aerator design calculations are included in Appendix 5-3.

Sludge Handling System

The sludge handling system includes the following major items of equipment:

- (2) 39,500 gallon capacity aerated biological sludge holding tanks with decant mechanisms. This volume provides approximately fifteen days retention at design conditions and will enable reductions of the volatile organics fraction of the sludge solids and will provide system storage.
- (1) 2000 gallon capacity gravity sludge thickener mounted beneath the inclined plate settler. The unit includes a mechanical scraper type sludge collector.
- (1) sludge conditioning tank to blend sludge with conditioning chemicals.
- chemical feed systems for sludge conditioning prior to dewatering including provisions to feed polymer, ferric chloride and diatomaceous earth or lime slurry.

- (1) plate and frame pressure filter with approximately 39 cf press volume.
- (2) air operated high pressure filter feed pumps.

The sludge dewatering system will likely require three filter press cycles per day, five days per week when the facility is placed into service based on the expected design loadings. The filter press is expected to operate on a 4 hour cycle (approximately) and will discharge dewatered sludge cake into a container suitable for discharge to a sludge hauling vehicle.

5.04 Site and Ancillary Systems Description

5.04.01 Site Plan

The ground water treatment facility is located adjacent to the gas extraction building. This location is within the site property lines, outside the known limits of refuse, above the 100 year flood level and not located in wetlands. Additionally, the site is convenient to the access road, utility entrance locations and provides easy routing for the effluent sewer.

As the proposed structures are approximately 900 feet from the public road and 800 feet from the nearest residence and the view of the proposed structures will be obstructed by trees, visual impact will be limited.

The layout of the proposed structures, tanks, and equipment is arranged in a plan to provide optimal use of floor space, minimum land requirements and easy access for operator attention. The proposed layout provides for four exterior tanks:

T - 101 Ground Water Flow Equipment Tank

T - 102 LGC Flow Equalization Tank

Q - 101A/B Sequencing Batch Reactor Tanks (2)

T - 110-Carbon Filter Backwash Tank

5.04.02 Process Equipment Building

A process equipment building is located adjacent to the tanks and will house the following major components and systems:

- metals removal system
- upflow sand filters
- carbon adsorption units
- intermediate process tanks
- process pumps
- chemical storage and feed equipment (partial)
- process blowers
- sludge filter press

Additionally, floor space is allocated for the following:

- power distribution and control
- storage of chemicals
- plant control room
- office space
- control laboratory
- lavatory/shower/locker room
- miscellaneous storage

The process equipment building is proposed to be a pre-engineered steel framed structure with aluminum siding and roofing panels matching the adjacent gas extraction building.

The southern half of the process equipment building houses the liquid treatment process systems including the metals removal system, upflow sand filters and carbon adsorption units.

The northern half of the building houses the sludge filter press and some of the facility's chemical feed equipment. Corrosive materials are stored and metered from the Gas Extraction Building. The acid drums are contained by a portable drum pallet, and the caustic is contained by a separate pallet of the same type.

5.04.03 Process Control and Instrumentation

The level of process control and instrumentation systems includes sufficient hardware to monitor system performance and control certain elements of the process.

The design basis for the instrumentation and control system includes sufficient control devices so that unattended second shift and third shift is possible.

The instrumentation and control system will be provided to include a highly reliable operating system due to the incorporation of critical alarms, system status monitoring and key system controls.

5.04.04 Outfall

A gravity outfall pipeline to convey treated effluent will extend from the south end of the process equipment building in a westerly direction passing beneath the plant entrance road to a discharge point west of the entrance road. A hydraulic cascade is located at the end of the outfall which serves as a post aeration device.

5.04.05 Plant Water System

The ground water treatment facility will be equipped with a plant water system for hose bibbs and chemical solution/slurry make-up. The plant water system will consist of a plant water pump, hydropneumatic tank, piping and valves.

5.04.06 Potable Water System

A potable water system will also be provided for the facility when municipal water is available to the site. The system will connect to a municipal water source at the properly line, and will be used for lavatories, the control lab and eye wash showers. The on-site water line is sized to meet potable water needs and serve two on-site fire hydrants.

5.04.07 Sanitary Sewer

A septic tank and associated leachate field are included as a sanitary sewer system for the facility.

5.04.08 Natural Gas

Natural gas service is provided to the facility via an on-site gas line connected to the utility along Parker Road. The gas line is sized to meet heating needs of the buildings.

SECTION 6 - TECHNICAL SPECIFICATIONS

The following specifications will be used to implement the design of the road, cap gas collection system and ground water treatment system components of the remedial construction for the Combe Fill South Landfill:

VOLUME 2A

DIVISION 1

GENERAL REQUIREMENTS

01010 Summary of Work
01015 Payment Item Descriptions
01020 Special Provisions
01100 Special Project Procedures
01105 Permits
01110 Safety, Health, and Emergency Response
01120 Environmental Protection
01125 Construction Water Management
01130 Spill and Discharge Control
01140 Decontamination Protocol
01400 Contractor Quality Control
01411 Operation Services
01510 Security
01520 Temporary Utilities and Controls

DIVISION 2

SITEWORK

02000 Field Office Trailer
02001 Project Sign
02110 Clearing
02220 Earthwork
02221 Test Pit Excavation and Backfilling
02222 Embankment
02224 Structural Excavation, Backfill, & Compaction
02226 Trenching, Backfilling, & Compaction
02228 Rock Removal
02229 Fill/Refuse Relocation
02230 Select Fill

DIVISION 2 (Continued)

02260 Shallow Ground Water Recovery Wells
02263 4-Inch Ground Water Monitor Wells
02265 2-Inch and 6-Inch Ground Water Monitor Wells
02267 Bedrock Monitor Wells
02268 Off-Site Bedrock Monitor Wells
02270 Erosion and Sediment Control
02271 Dumped Rip-Rap
02275 Erosion Control Matting
02280 Drum Removal
02289 Soil Barrier Layer Test Section
02290 Soil Barrier Layer
02291 Soil Barrier Layer with Bentonite
02292 Drainage Layer
02293 Vegetative Layer
02294 Flexible Membrane Cover
02296 Geotextiles Used as Filter Fabrics
02297 Gabions
02299 Gas Extraction Wells
02502 Restoration of Surfaces
02510 Bituminous Concrete Pavements
02600 Pipeline Installation
02602 Leakage Tests
02612 Reinforced Concrete Non-Pressure Pipe
02620 Polyvinyl Chloride Non-Pressure Pipe
02621 Perforated Polyvinyl Chloride Drainage Pipe
02628 Ductile Iron Pipe
02645 Fire Hydrants
02675 Chlorination
02713 Plant Water System
02720 Vaults and Inlets
02730 Precast Concrete Manholes
02830 Chain Link Fences and Gates
02980 Topsoil and Seeding

DIVISION 3

CONCRETE

03001 Concrete
03307 Concrete for Pipelines, Vaults and Inlets

DIVISION 4

MASONRY

04100 Mortar
04300 Unit Masonry System
04340 Reinforced Unit Masonry System

DIVISION 5

METALS

05500 Metal Fabrications
05510 Metal Stairs
05520 Handrails and Railings
05531 Grating and Floor Plates

DIVISION 6

WOOD AND PLASTICS

06114 Wood Blocking, Curbing and Framing
06125 Wood Decking

DIVISION 7

THERMAL AND MOISTURE CONTROL

07160 Bituminous Dampproofing
07212 Board Insulation
07213 Batt and Blanket Insulation
07900 Joint Sealers

DIVISION 8

DOORS AND WINDOWS

08111 Standard Steel Doors
08112 Standard Steel Frames
08331 Overhead Coiling Doors
08710 Door Hardware

DIVISION 9

FINISHING

09260 Gypsum Board Systems
09511 Suspended Acoustic Ceilings
09650 Resilient Flooring
09900 Field Painting

DIVISION 10

SPECIALTIES

10165 Plastic Laminate Toilet Compartments
10210 Metal Wall Louvers
10441 Plastic Signs
10522 Fire Extinguishers, Cabinets and Accessories
10800 Toilet and Bath Accessories

VOLUME 2B

DIVISION 11

EQUIPMENT

11219 Mechanical Mixers
11220 Submersible Mixers
11230 Submersible Aerator
11231 Chemical Feeding Equipment
11300 Condensate Pump Station Equipment
11311 Adsorbent Carbon Filter Unit
11340 Floating Skimmer
11370 Plate and Frame Filter Press
11372 Air Compressors and Blower
11381 Landfill Gas Exhausters
11382 Gas Handling Equipment
11600 Laboratory Equipment and Supplies

DIVISION 12

12301 Metal Casework

DIVISION 13

SPECIAL CONSTRUCTION

13121 Pre-Engineered Buildings
13190 Enclosed Flare
13406 Carbon Adsorption Units
13407 Continuous Sand Filters
13408 Sequencing Batch Reactors
13409 Inclined Plate Settler
13411 Welded Steel Storage Tanks
13415 Fiberglass Reinforced Plastic Storage Tanks

DIVISION 15

MECHANICAL

15050 High Density Polyethylene (HDPE) Pressure Pipe
15061 Steel Piping
15064 Polyvinyl Chloride (PVC) Pressure and Vacuum Pipe
15067 Epoxy Resin Fiberglass Reinforced Pipe
15099 Composite Sampling Units
15100 Valves-General
15103 Butterfly Valves
15104 Ball Valves
15111 Check Valves 3" and Larger
15115 Gate Valves Three Inches and Larger
15124 Wall Castings and Sleeves
15125 Miscellaneous Valves and Traps
15130 Pressure Gauges
15140 Supports and Anchors
15141 Centrifugal Pumps
15146 Vertical Non-Clog Submersible Pumps
15163 Pneumatic Diaphragm Pumps
15164 Flexible Connectors
15165 Diaphragm Metering Pumps
15170 Miscellaneous Electrical Motors
15190 Mechanical Identification
15260 Piping Insulation
15290 Ductwork Insulation
15330 Automatic Sprinkler System
15350 Natural Gas Piping Systems
15410 Plumbing Piping
15430 Plumbing Specialties
15440 Plumbing Fixtures
15450 Plumbing Equipment
15575 Breeching, Chimneys and Stacks

DIVISION 15 (Continued)

15783 Room Air Conditioning Units
15800 Pumps-General
15835 Terminal Heat Transfer Units
15855 Air Handling Units with Coils
15860 Centrifugal Fans
15865 Inline Fans
15870 Power Ventilators
15890 Ductwork and Accessories
15936 Air Outlets and Inlets
15970 Temperature Controls
15988 Tests on Pumping Equipment
15989 Recovery Well Pumps
15990 Testing, Adjusting and Balancing

DIVISION 16

ELECTRICAL

16010 Electrical General
16095 Electrical Systems Identification
16111 Conduits
16120 Wires and Cables
16141 Wiring Devices
16160 Enclosures
16352 Motor Controllers
16400 Incoming Services
16450 Electrical Grounding
16470 Panelboards and Circuit Protective Devices
16480 Motor Control Centers
16510 Lighting Equipment
16859 Electrical Heat Trace System
16900 Instrumentation General
16902 Miscellaneous Electrical Controls
16903 Programmable Controllers
16911 Variable Frequency Drive Equipment

These specifications will be developed in Construction Specification Institute (CSI) format.

SECTION 7 - SAFETY AND HEALTH CRITERIA

7.01 General

A Safety, Health, and Emergency Response Plan (SHERP) will be required for remedial construction activities at the Combe Fill Landfill. The following sections discuss the minimum requirements for an acceptable SHERP including site personnel, monitoring, and contingency plan requirements. In addition, potential health hazards and contaminants likely to be present during various construction activities and the corresponding recommended control measures are presented.

7.02 Organizational Chart and Resumes

An organizational chart and resumes of key personnel involved in all phases of the Combe Fill South Remedial Design Construction must be provided. The chart must identify the following by name:

- Senior Manager
- Project Manager
- Health and Safety Officer (HSO)
- Field Supervisor
- Foremen

The Health and Safety Officer (HSO) shall have the following authorities and responsibilities:

- The HSO shall be present at all times during site operations.
- The HSO shall have the authority to enforce the SHERP and stop operations if the safety or health of site personnel is jeopardized.

- The HSO shall evaluate all monitoring data and make necessary field decisions regarding site health and safety procedures.
- The HSO may require evacuation of the site if necessary to protect the safety and health of workers.

In addition, the health and safety officer shall have the following minimum qualifications:

- Possess a sound working knowledge of State and Federal occupational safety and health regulations.
- Have formal educational training in occupational safety and health.
- Have a minimum of four (4) years experience in the environmental and health and safety services field, chemical industry, or chemical waste disposal industry, more than 50% of which must be in the area of industrial hygiene and/or environmental safety.
- Have the authority and knowledge necessary to implement the site SHERP and verify compliance with applicable safety and health requirements.

7.03 Operation Risk Analysis

A health and safety risk analysis shall be performed and provided by the Contractor for each operation to be performed.

The risk analysis shall be based upon the best information available regarding the contaminants and conditions present at the site as well as the practices and tools to be applied in the operation and shall include but not be limited to the following:

1. Description of the operation and tasks to be performed.

2. Approximate duration of the operation and of each task.
3. An evaluation (including the use of chemical safety data sheets) of the known or suspected contaminants and conditions that may pose health hazards.
4. An evaluation of known or potential safety hazards associated with each task.
5. Known or suspected pathways of contaminant dispersion pertinent to the operation and tasks performed.
6. Site accessibility.
7. Site topography and special features (e.g. structures, tanks, etc.) affecting activities.

The SHERP shall include a discussion of the Site Standard Operating Procedures for activities to be performed on the site. Development of the Site Standard Operating Procedures, identification of required documents, and their collection will be the responsibility of the Project Manager and the Field Supervisors. The Standard Operating Procedures Incorporated shall include a listing of the Standard Operating Procedures used in the SHERP plan.

In the following sections, operations and tasks to be performed for various construction activities are discussed. Potential expected contaminants, contaminant dispersions pathways, and contaminant control are also presented.

7.03.01 Site Grading Operations

Operations and tasks to be performed during site grading will include the grading of materials required for site preparation, installation of the cover system, and installation of drainage structures. Grading may require the movement of the refuse and thus release dust and cause potential off-gassing from re-exposed sub-surface material.

The expected contaminants include methane, hydrogen sulfide and vinyl chloride, as identified as components of the gases within the landfill in the Preliminary Design Report. These gases may be released at levels at or above Permissible Exposure Levels (PEL) and, if found at these levels, will be present as potential inhalation hazards. In addition, the gases may generate an offensive smell at concentrations below the PEL. Benzene, ethylbenzene, toluene, tetrachloroethylene and trichloroethylene were identified in the water and air effluent from the site. The potential for their release exists as well, although it is anticipated that these levels do not present an inhalation or skin contact hazard. There may also be odors associated with decomposing refuse and blowing dust and refuse.

Contaminants may be spread through the air and as part of the dust and airborne solid material generated. Contaminant control may be accomplished by providing adequate dust protection through the use of dust resistant coveralls and wearing eye protection. Air purifying respirators with dust filters and vinyl chloride cartridges may be necessary. These cartridges do not provide protection against hydrogen sulfide. A continuous air monitoring device for hydrogen sulfide will be necessary within each earthmover.

7.03.02 Installation of the Shallow Ground Water Recovery Wells

Installation of the shallow ground water recovery wells will require drilling of the wells and backfilling of the borehole. During drilling, potential safety hazards common to drilling operations may result. Methane, hydrogen sulfide and vinyl chloride were identified in preliminary design report as being components of the gases within the landfill. These gases may be released at levels at or above Permissible Exposure Levels and, if found at these levels, may present inhalation hazards. Benzene, ethylbenzene, toluene, tetrachloro-ethylene and trichloroethylene were identified in the water and air effluent from the site. The potential for their release exists, although it is anticipated that the levels do not present an inhalation or skin contact hazard. They may generate an offensive smell at concentrations below the PEL.

The contaminants may be spread through the air. Contaminant control may require air purifying respirators with organic vapor cartridges and clothing to resist water splash. Direct reading instruments must be used for monitoring hydrogen sulfide and vinyl chloride levels during the drilling and vent setting operations.

7.03.03 Installation of the Gas Extraction Wells

Installation of the gas extraction wells will involve drilling of the wells and backfilling of the borehole. During drilling, potential health hazards common to drilling may result. In addition, the potential for release of methane and other gases as a result of encountering pockets of these materials in the refuse exists. The possibility also exists of splashing of the well contents onto workers and inspectors. Methane and other gases may collect in the wells.

The contaminants may be spread through the air. Adequate health protection may be provided by use of air purifying respirators with vinyl chloride cartridges. These cartridges do not provide protection against hydrogen sulfide. Water resistant coveralls, eye protection and water resistant gloves may be necessary during handling of the newly exposed materials. Standard safety practices for well drilling should be used to minimize the effect of striking submerged materials and gas pockets. Explosive gas meters should be used to measure methane concentrations. Direct reading instruments should be used for monitoring hydrogen sulfide and vinyl chloride levels during the drilling operations.

7.03.04 Construction of Drainage Pipe System

Installation of the drainage pipes in the cap drainage layer is planned to be completed following site grading and installation of the soil barrier layer. There are no expected contaminants and, therefore, there should be no contaminants released from the landfill. Safety hazards may potentially result from the construction operation and will be addressed by existing construction safety and health operating procedures.

7.03.05 Installation of the Cap System

Installation of the cap system may involve the construction of a soil barrier layer overlying the graded refuse. Following installation of the soil barrier layer, a drainage layer and vegetative layer is planned to be constructed. Potential health hazards may result from exposure to gases within the landfill during installation of the soil barrier layer. Methane, hydrogen sulfide and vinyl chloride were identified in preliminary design material as being components of those gases. These gases may be released at levels at or above Permissible Exposure Levels and, if found at these levels, may present an inhalation hazard. Benzene, ethylbenzene, toluene, tetrachloroethylene and trichloroethylene were identified in the water and air effluent from the site. The potential for their release exists, although it is anticipated that the levels do not present an inhalation or skin contact hazard. The mixture of gases may also generate an offensive smell at concentrations below the respective PEL. There may also be odors associated with decomposing refuse and blowing dust and refuse. If sand is used in construction of the drainage layer, the potential hazard of the silica content of the sand exists.

The dusts and gases may become airborne. Adequate dust protection for personnel dumping and spreading earth materials should be provided by using dust resistant coveralls and wearing eye protection. Air purifying respirators with dust filters and vinyl chloride cartridges may be necessary. These cartridges do not provide protection against hydrogen sulfide. A continuous air monitoring device for hydrogen sulfide may be necessary within each piece of construction equipment.

7.03.06 Ground Water Treatment System

Shallow ground water discharged from the unconsolidated aquifer surrounding the site is planned to be collected by recovery wells and directed to the ground water treatment facility for on-site treatment. Methane, hydrogen sulfide and vinyl chloride were identified in preliminary design report as being components of the gases within the landfill. These gases may be released at levels at or above Permissible Exposure Levels and, if found at these levels, may present an inhalation hazard. Benzene, ethylbenzene, toluene, tetrachloroethylene and trichloroethylene were identified in the water and air effluent from the site. The potential for their release also exists, although it is anticipated that the levels do not present an inhalation or skin contact hazard. They may also generate an offensive smell at concentrations below the PEL.

The materials will be released as gaseous materials and/or in splash from the pipelines or other system components. Adequate health protection during handling of the system component may be provided by use of water resistant coveralls, eye protection and water resistant gloves. Air purifying respirators with vinyl chloride cartridges may be necessary. These cartridges do not provide protection against hydrogen sulfide. A continuous air monitoring device for hydrogen sulfide may be necessary to accompany each line inspector.

7.03.07 Monitoring of Construction Water

Samples of construction water generated at the site may be collected and analyzed. Methane, hydrogen sulfide and vinyl chloride were identified in the preliminary design report as components of the gases within the landfill. These gases may be released at levels at or above Permissible Exposure Levels and, if found at these levels, will present an inhalation hazard. Benzene, ethylbenzene, toluene, tetrachloroethylene and trichloroethylene were identified in the water and air effluent from the site. The potential for their release also exists, although it is anticipated the levels do not present an inhalation or skin contact hazard. They may also generate an offensive smell at concentrations below the PEL.

The contaminants will be spread through the air. Adequate health protection during sampling activities should be provided by use of water resistant coveralls, eye protection and water resistant gloves. Air purifying respirators with vinyl chloride cartridges may be necessary. These cartridges do not provide protection against hydrogen sulfide. A continuous air monitoring device for hydrogen sulfide may be necessary.

7.04 Employee Training

7.04.01 Training Requirements for On-Site Personnel

All employees performing on-site activities must meet one of the following requirements within the 12 months prior to the start of work at the site:

- A 40 hour, minimum, hazardous materials safety and health course, meeting the requirements of 29 CFR 1910.120 e(3).
- An eight (8) hour, minimum, refresher course meeting the requirements of 29 CFR 1910.120 e(8).
- Equivalent documentable work experience demonstrating a knowledge of safety and healthful work practices as stipulated in 29 CFR 1910.120 e(9).

On-site management and supervisors directly responsible for or who supervise employees engaged in site operations, including the on-site health and safety officer, shall have also received eight (8) hours additional training in managing such site operations meeting the requirements of 29 CFR 1910.120 e(4) prior to the start of site work.

Employees who have been designated as responsible for responding to on-site emergencies shall have received additional training meeting the requirements of 29 CFR 1910.120(q) in how to respond to such expected emergencies prior to the start of site work

Employees who have not received the required training are not to engage in work on site until such training has been completed.

<u>**7.04.02 Employee Training Program**</u>

The Contractor shall include in the SHERP a summary of the hazardous materials safety and health training program and a list of elements and topics covered.

7.04.03 Program Certification

The Contractor shall provide written certification of completed training and/or acquired experience for all employees designated to engage in on-site activities.

The written certification of training shall be maintained on site for each employee, supervisor and emergency responder requiring training. Such certification shall be supplied prior to the start of on-site activities.

Such certification shall be endorsed by a member of top level management, a corporate officer, or the health and safety program manager and shall be incorporated into the SHERP for the project.

7.04.04 Site Specific Training

The Contractor shall provide site specific training and perform daily safety briefings that will provide an awareness of planned operations, the site specific SHERP, the form and warning properties of potential hazards, work zones, locations of emergency/safety equipment, local emergency response procedures, site characteristics, levels of protection, communications, decontamination procedures, emergency facilities and signals, and evacuation procedures.

7.05 Medical Surveillance

The Contractor shall establish and implement a medical surveillance program (MSP) for employees engaged in on-site operations, consistent with 29 CFR 1910.120(f). The MSP program shall include physical examinations administered by a board certified physician familiar with internal or occupational medicine. The Contractor shall include the name and business address of the administering physician in the SHERP. The Contractor shall include the components of both the MSP program and the physical examination in the SHERP. The Contractor shall address the need for personal exposure monitoring and post exposure medical screening in the SHERP and include a description of those provisions.

The medical surveillance program should consist of an examination prior to the start of work for factors related to exposure to hydrogen sulfide, benzene, vinyl chloride, ethylbenzene, toluene, tetrachloroethylene and trichloroethylene. Those employees installing the cap system may also be evaluated for factors related to exposure to silica containing dusts. The examination should be repeated at the end of work or on the anniversary of the initial exam, if the work is still ongoing.

Medical records and personnel exposure monitoring data will be maintained in accordance with established procedures for maintenance of such records, as described in Subpart C of 29 CFR 1910.20. The examining physician will provide each employer and each employee with a certificate (or equivalent medical report) of medical fitness to perform the work required. A copy of the physician's report of medical fitness for each employee will be maintained on the site. Such certification shall be endorsed by a member of top level management, a corporate officer, or the health and safety program manager and shall be incorporated into the site SHERP.

Formal training in prevention of heat and/or cold injuries will be provided as part of the site specific training and repeated in October and April of each year. Informal review of these techniques will be made a part of daily pre-work briefings. A heat stress prevention program will involve a monitoring program as follows:

- When the outdoor wet bulb globe temperature exceeds 86 degrees F, a log of oral temperatures will be established for each worker on the site. The work period of workers with oral temperatures in excess of 101 degrees F after the rest period will be reduced by 33% until the oral temperature returns below 101 degrees F.

A cold injury prevention program will involve a monitoring program as follows:

- When the outdoor dry bulb temperature is less than 40 degrees F., a warming tent or other facility will be established for each work area that has personnel working outdoors on the site.
- When the outdoor dry bulb temperature is less than 40 degrees F., a log of oral temperatures will be established for each worker working outdoors on the site. The outdoor period for workers with oral temperatures below 97 degrees F will be reduced by 33% until the oral temperature returns above 98 degrees F.
- When the outdoor dry bulb temperature is less than 30 degrees F., the windspeed and air temperature will be recorded at least once during every four hour period. The guidance of Table 6, TLV Reference, will be followed in establishing minimum warm-up break schedules.

7.06 Air Monitoring

7.06.01 Initial Monitoring

Air monitoring shall be performed during the accomplishment of the following tasks:

- Site Grading
- Installation of the Shallow Ground Water Recovery Wells;
- Installation of the Gas Extraction Wells;
- Installation of the Cap System;
- Operation of the Shallow Ground Water Treatment Facility;
- Monitoring of the Construction Water.

The contaminants of concern are expected to include methane, hydrogen sulfide and vinyl chloride. Concentrations of these contaminants are expected to be below the OSHA Permissible Exposure Limits.

The Contractor shall establish and implement an air monitoring program to identify areas of suspected elevated airborne contaminant concentrations and to determine the concentration levels. The Contractor shall provide the personnel, instruments, and materials necessary to perform such air monitoring and identify the individual responsible for administering the program. The program shall be included in the SHERP. The air sampling program shall include initial and subsequent measurements. The Contractor must determine the frequency of air measurements and locations to be monitored.

The Contractor must incorporate the following information into the air monitoring program:

- Type, make, and model of instrument(s) selected for use.
- All instrument settings for each instrument used.
- Method of instrument calibration, including calibrant and sample calibration data sheet.

- Manner and frequency of field calibration checks...

Instruments to be used during the monitoring program shall include an explosive gas monitor calibrated for methane and appropriate direct reading instrument for hydrogen sulfide and vinyl chloride measurement. The sampling devices and pumps must be approved for use in combustible or flammable atmospheres.

The instruments will be calibrated according to manufacture's instructions at the beginning of each workshift that they will be used. Monitoring for methane should be continuous and monitoring for vinyl chloride and hydrogen sulfide should be at 15 minute intervals during active work unless a continuous reading monitor is available. Records meeting the requirements of 29 CFR 1910.20 shall be kept of all of the air monitoring done for health and safety protection.

The explosive gas monitor shall be set to read in percent of the Lower Explosive Limit (% LEL). Readings of greater than 25% LEL shall require evacuation of all except the monitoring personnel. The monitoring personnel shall re-evaluate the environment after allowing the escaping gas to be diluted by the surrounding air. Re-entry should not be allowed until the explosive gas concentration has been reduced below 20% LEL.

The hydrogen sulfide and vinyl chloride instruments must be set to read in parts per million (ppm). Readings greater than 1 ppm of vinyl chloride or 10 ppm of hydrogen sulfide shall require the use of air purifying respirators with appropriate chemical canisters. Readings greater than 10 ppm of vinyl chloride or 100 ppm of hydrogen sulfide shall require evacuation of all except the monitoring personnel. The monitoring personnel must wear air supplying respirators when re-evaluating the environment after allowing the escaping gas to be diluted by the surrounding air.

7.06.02 Continued Monitoring

The Contractor shall examine, and report to the Engineer's/NJDEP's satisfaction the need, or lack thereof, to continue the area and personnel air sampling program during the project, based upon adequate initial Area and Personnel air sampling episodes.

Special considerations shall be given to intrusive or high-risk tasks and the potential for exposure to those performing such tasks. For the Combe Fill South Landfill these high risk tasks include the removal and relocation of refuse on site, drum excavation, and the installation of the water and gas collection wells.

The sampling devices, pumps, collection media, and any necessary support equipment shall be appropriately assembled into a sampling train, and each resultant sampling train shall be flow calibrated as a complete system before and after each day's use against a primary standard.

The Contractor shall maintain a sampling record as part of the air sampling program. The record must include, as a minimum, the following:

- Collection date
- Sample identification number
- Location and/or task sampled
- Instrument/sampling train used

- Duration of sampling
- Ambient temperature, humidity and wind speed
- Sampling results (instrument readings, laboratory report, etc.)
- Pre- and post- sampling train flow calibration
- Any pertinent comments

The laboratory selected for sample analysis must be accredited by the AIHA for the analyses required. Sampling and analytical methods of NIOSH or OSHA must be used preferentially when such methods are available for the samples collected and all appropriate QC and QC provisions regarding sample collection, transport, and holding times must be followed.

7.06.03 Records Retention and Data Reporting

The Contractor shall retain all personnel exposure sampling results in accordance with the requirements set forth in OSHA, Subpart C of 29 CFR 1910.20(d). The Contractor shall follow all other pertinent provisions of that regulation.

The Contractor shall submit, in writing, the analytical results from any area and personnel samples collected within 30 working days of the collection of each sample. If applicable, sample flow rates in liters per minute (lpm) and sampling periods in minutes for each sample collected must be reported with the analytical results. Sample locations or tasks and identification numbers shall also be reported.

The Contractor shall report verbally all data resulting from daily air monitoring to the on-site State representative, at a minimum, at the end of the work period. If at any time the instrumentation indicates an adverse change in conditions, the HSO must notify the State representative immediately and follow up this reporting in writing by the close of business on that day.

The Contractor shall furnish copies of the daily air monitoring log to the State representative, at a minimum, weekly, unless otherwise noted or arranged.

7.07 Personnel Protection

7.07.01 Engineering and Work Practice Controls

The Contractor must consider the ability to apply engineering and/or work practice controls to protect personnel during the performance of site tasks. When practicable, engineering controls shall be implemented to reduce and maintain employee exposures to or below safe levels for those tasks demonstrating known or suspected hazards. Work practice controls shall next be applied when engineering controls are impracticable and shall be incorporated as site specific standard operating procedures (SOP) for recurring, routine operations.

7.07.02 Personnel Protective Equipment and Levels of Protection

The Contractor shall use personnel protective equipment (PPE) only when engineering and/or work practice controls have been deemed impractical or insufficient to protect employees during site operations. The Contractor shall select PPE based on an evaluation of performance characteristics, site specific tasks, and known or suspected hazards and shall assemble the PPE into levels of protection (LOP) or ensembles appropriate for the site. The Contractor shall include in the SHERP a list of components for each protective ensemble, the LOP selected for each task, the rationale for each task-specific selection, and any contaminant action levels to be followed in LOP decision making.

These specific tasks for the Combe Fill South Remedial Design construction shall include:

- Site preparation
- Construction of erosion and sediment control structures
- Installation of security fence
- Site grading/earth moving
- Handling and disposal of construction water and contaminated water
- Refuse excavation and relocation on site
- Excavation of drums found on site
- Installation of Shallow Ground Water Recovery System
- Construction of on-site ground water treatment plant
- Installation of cap
- Installation of gas wells
- Installation of gas collection system
- Installation of ground water monitoring wells
- Ground water monitoring
- Surface water monitoring

USEPA Level B protection shall be required when the vinyl chloride and/or hydrogen sulfide levels exceed the action levels specified above for the use of air-supplying respirators. Level C protection shall be required when the action levels for the contaminants exceed the action levels or the operation requires the use of such protection without monitoring. Air purifying respirators that meet NIOSH/ MSHA standards for protection against organic vapors, vinyl chloride and hydrogen sulfide shall be provided. Contaminant action levels are as previously discussed. A respiratory protection program meeting the requirements of 29 CFR 1910.134 must be established. Other personal protective equipment supplied must be purchased and maintained in accordance with the applicable provisions of Subpart G, 29 CFR 1910.

The Contractor shall establish a PPE program addressing the following elements:

- Site hazards
- Duration of site operations
- PPE selection criteria
- PPE use and limitations
- PPE maintenance and storage
- PPE decontamination
- PPE training and proper fit
- Donning and doffing procedures
- PPE inspection
- PPE in-use monitoring

- Evaluation of program effectiveness
- Heat stress and cold injury prevention while using PPE

7.07.03 Respiratory Protection

The Contractor shall include a description of his respiratory protection program and the method of respirator fit testing employed. The Contractor shall use only NIOSH/MSHA approved respiratory protective equipment.

7.08 Confined Space Operations

For activities within confined spaces, the Contractor shall develop and implement SOPs in accordance with the NIOSH "Guide to Safety in Confined Spaces", NIOSH publication No. 87-113 (Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402) and shall incorporate them in the SHERP. Guidance within 29 CFR 1926.21(b)(6) and the proposed OSHA confined space regulation, 29 CFR 1910.146, may be used.

Pre-entry briefings shall be held prior to initiating any confined space entries and at other times as necessary to ensure that employees are aware of the SHERP provisions governing such activities and that they are being followed.

Inspections shall be conducted by the HSO or, in the absence of that individual, another qualified individual acting on behalf of the Contractor as necessary to determine the effectiveness of the SHERP and associated confined space SOPs. Any deficiencies in effectiveness shall be corrected by the Contractor.

The Contractor shall ensure that the HSO or, in the absence of that individual, another qualified individual acting on behalf of the Contractor shall test the atmosphere of the confined space prior to entry and that all measures necessary to protect the health and safety of employees entering the space have been taken.

Potential confined space hazards identifiable in the work plan during the construction phase are those of creating the gas extraction and treatment system and the shallow ground water recovery and treatment system. These spaces shall remain and must be entered as part of the system's maintenance programs. All confined spaces shall be tested for explosive gases and oxygen level prior to entry. Continuous monitors with alarms shall be used whenever the spaces are occupied. The monitoring manholes must be entered with caution if the explosive gas level exceeds 10% LEL and shall not be entered if the explosive gas level exceeds 25% LEL. Procedures must be developed to provide air movement in the inspection manholes to reduce the concentration of explosive gases below 10% LEL.

7.09 Site Control

Site control procedures shall be established to reduce the possibility of worker contact with any contaminants present, to protect the public in the area surrounding the site by preventing the movement of contaminated materials and contaminants from the site and to limit access to the site to only those personnel required to be on it. Work zones that will accomplish this general objective shall be established by the project manager working with the HSO.

7.09.01 Routine Requirements

During ongoing operations, the Contractor and/or his designee shall be required to meet with the on-site State representative, when present, prior to the start of the day's activities to prepare necessary paperwork and outline the day's activities. The Contractor shall also meet with the on-site State representative at the completion of the day's activities to discuss the work performed.

The project manager and the HSO shall establish a system appropriate to the site, the work and the work zones that will provide communications within and off the site. In addition, the project manager and the HSO shall establish a system that will provide an emergency communications system within the site and to emergency responders off the site. A system that will record, as a minimum, the following information shall be established:

- Personnel on the site, their arrival and departure times and their destination on the site;
- Incidents and unusual activities that occur on the site such as, but not limited to, accidents, spills, breaches of security, injuries, equipment failures and weather related problems;
- Conversations that may affect the work such as media visits, safety and health inspections (by the HSO and external agencies), owner/agent meetings, and employee/union meetings;
- Changes to the Work Plan and the SHERP;

- Daily Information generated including changes to work and health and safety plans, work accomplished and the current site status, and air monitoring results.

<u>7.09.02 Work Zones</u>

The Contractor shall be responsible for conducting operations at the site in such a controlled fashion as to reduce the possibility of contact with any contaminants present and to prevent the removal of contaminants by personnel or equipment leaving the site.

The Contractor shall delineate work zones in which specific operations or tasks will occur and shall institute specific site entry and decontamination procedures at designated control points. Three (3) work zones shall be established to perform this work: an exclusion/contamination zone, a contamination/reduction zone and a support/clean zone. A map or diagram showing the work zones and a description of the site control plan shall be included in the SHERP. The map depicting these work zones will be posted in a conspicuous location and reviewed during the daily safety briefings.

The Contractor shall include any standard operating procedures pertaining to site control in the SHERP and shall incorporate plans for routine and emergency communications appropriate for the site and project.

The Contractor shall keep a daily log, copies to be provided to the State/Engineer upon request. This log shall include:

- Personnel visiting the site
- Affiliation

- Date
- Arrival time
- Departure time
- Purpose of visit

No unauthorized personnel shall be permitted to enter the site, prior to the start of operations. The Contractor shall provide the State representative a list of all Contractor and subcontractor personnel who are authorized to enter the site, updating the list as necessary. Predesignated State personnel shall have unlimited access to the site.

7.09.03 Decontamination

All personnel and equipment exiting the exclusion zone shall be decontaminated prior to entering the support zone. The project manager and the HSO shall establish a decontamination system and decontamination procedures to prevent potentially hazardous materials from leaving the site. The decontamination procedures shall be published as part of the site SOP's and be reviewed at each daily safety briefing. Personal hygiene facilities meeting at least the minimum requirements of 29 CFR 1910.120 shall be provided.

7.10 Emergency Response/Contingency Planning

7.10.01 Emergency Response Plan

The project manager and the HSO shall establish an emergency response plan appropriate to the site, the work and the work zones to handle anticipated on-site emergencies. The plan shall be reviewed daily to ensure its applicability for the planned day's operations. Employees who respond to emergency situations involving hazardous materials shall be trained in how to respond to such emergencies.

The contractor shall develop and implement an emergency response plan (ERP) prior to the start of site operations to handle anticipated on-site emergencies. The ERP shall be incorporated into the site SHERP as a separate section of that document and shall be periodically reviewed and, as necessary, amended to keep it current with new or changing site conditions or information.

The ERP shall address, as a minimum, the following:

- Pre-planning of site operations to prevent emergencies
- Personnel roles and lines of authority
- Key person at the site authorized and responsible for implementing the plan
- Emergency recognition and control measures
- Evacuation routes and procedures, frequency of drills
- Safe distances and places of refuge
- Emergency security and site control measures
- Emergency Decontamination
- Emergency medical treatment and first aid
- Emergency alerting and response procedures
- Site communications

- Site diagrams showing general layout, work zones, and prevailing weather conditions
- Procedures for reporting incidents to pertinent local, state, and federal agencies
- A list of emergency telephone contacts including the name, location, telephone number and route to the nearest medical facility that will provide emergency medical services if needed
- Measures to review and follow up on site responses
- Emergency and personal equipment kept at the site for emergencies

The Contractor shall attend public meetings or briefings, as necessary, to discuss and present the HASP and ERP.

7.10.02 Special Training

The Contractor shall ensure that at least one person holding up-to-date certifications (American Red Cross or equivalent) in basic first aid (8 hr minimum) and CPR is present at the site during all site operations.

7.10.03 Accident and Exposure Reports

The Contractor shall notify the State Construction Manager of all on-site accidents at the time of occurrence and follow up in writing within 24 hours. This notification shall include, but not be limited to, the date, time and identify to individual(s) involved in the accident, the nature of the accident, the actions taken to treat the victim(s), and the steps taken to prevent recurrence.

The Contractor shall notify the State Construction Manager of all person(s) exposed at the time of occurrence and follow up in writing within 24 hours. This notification shall include, but not be limited to, the date, time, and identify of individual(s) involved in the exposure, the nature of the exposure episode, what the individual(s) were exposed to, the engineering controls and work practices in use and the personal protective equipment worn during the exposure, and the steps taken to prevent recurrence.

7.11 Operations Within and Adjacent to the Power Line Corridor

For activities requiring the operation of cranes or derricks within or adjacent to the Power Line Corridor, the Contractor shall develop and implement SOP's in accordance with 29 CFR 1926.550(a) - Cranes and Derricks and incorporate them in the SHERP.

Derrick operations shall be directed only by the individual specifically designated by the Contractor for that purpose.

Except where electrical distribution and transmission lines have been de-energized and visibly grounded at point of work or where insulating barriers, not a part of or an attachment to the equipment or machinery, have been erected to prevent physical contact with the lines, equipment or machines shall be operated proximate to power lines only in accordance with 29 CFR 1926.550(a)(15). The Contractor shall designate a person to observe clearance of the equipment and give timely warning for all operations where it is difficult for the operator to maintain the desired clearance by visual means. Any overhead wire shall be considered to be an energized line unless and until the person owning such line or the electrical utility authorities indicate that it is not an energized line and it has been visibly grounded. Prior to work near transmitter towers where an electrical charge can be induced in the equipment or materials being handled, the transmitter shall be de-energized or tests shall be made to determine if electrical charge is induced on the crane. The precautions specified in 29 CFR 1926.550(a)(15)(vii) shall be taken when necessary to dissipate induced voltages.

Inspections shall be conducted by the HSO or, in absence of that individual, another qualified individual acting on behalf of the Contractor as necessary to determine the effectiveness of the SHERP and associated Power Line Corridor SOP's. Any deficiencies in effectiveness shall be corrected by the Contractor.

7.12 Rock Blasting Operation/Explosives Handling & Storage

Should site operations include activities requiring the blasting of rock and the handling and storage of explosives, the Contractor shall develop and implement SOP's in accordance with 29 CFR 1926, Subpart U, Blasting and the Use of Explosives and incorporate them in the SHERP.

The contractor shall permit only authorized and qualified, as stated in 29 CFR 1926.901, persons to handle and use explosives. Blasting operations above ground shall only be conducted between sunup and sundown. The blaster shall keep an accurate, up-to-date record of explosives, blasting agents, and blasting supplies used in a blast and shall keep an accurate running inventory of all explosives and blasting agents stored on the site.

Due precautions shall be taken by the contractor to prevent accidental discharge of electric blasting caps from current induced by radar, radio transmitters, lightning, adjacent powerlines, dust storms, or other sources of extraneous electricity. Blasting operations in the proximity of overhead power lines, communication lines, utility services, or other services and structures shall not be carried on until the operators and/or owners have been notified and measures for safe control have been taken.

Smoking, firearms, matches, open flame lamps, and other fires, flame or heat producing devices and sparks shall be prohibited in or near explosive magazines or while explosives are being handled, transported or used. Transportation of explosives shall meet the provisions of Department of Transportation regulations contained in 49 CFR Parts 171-179, Highways and Railways, and 49 CFR Parts 390-397, Motor Carriers.

Inspections shall be conducted by the HSO or, in absence of that individual, another qualified individual acting on behalf of the Contractor as necessary to determine the effectiveness of the SHERP and associated explosive handling SOP's. Any deficiencies in effectiveness shall be corrected by the Contractor.

7.13 Drum Excavation Operations

Should site operations include activities requiring the excavation and handling of drums, the Contractor shall develop and implement SOP's in accordance with 29 CFR 1910.120(j) - Hazardous Waste Operations and Emergency Response, Handling Drums and Containers and incorporate them in the SHERP.

Prior to movement of drums or containers, all employees exposed to the transfer operation shall be warned of the potential hazards associated with the contents of the drums or containers. The procedures specified in 29 CFR 1910.120(j)(2) shall be followed in areas where drums or containers are being opened. Hazardous substances and contaminated soils, liquids, and other residues shall be handled, transported, labeled, and disposed of in accordance with 29 CFR 1910.120(j)(1)(i).

Inspections shall be conducted by the HSO or, in absence of that individual, another qualified individual acting on behalf of the Contractor, as necessary to determine the effectiveness of the SHERP and associated drum handling SOP's. Any deficiencies in effectiveness shall be corrected by the Contractor.

7.14 Decontamination

All personnel and equipment exiting the Exclusion/Contamination zone must be decontaminated prior to entering the Support/Clean zone. This decontamination must be perform in order to prevent contamination from being transferred into clean areas and contaminating or exposing unprotected personnel.

The Contractor shall develop and implement personnel and equipment decontamination procedures appropriate for the site and include those procedures in the site SHERP. The procedures shall include the necessary equipment and personnel and the steps to achieve the objective, provisions for any personnel protection, and a diagram outlining the steps or stations in the procedures. The procedures must ensure adequate containment and removal of any decontamination solutions and spent disposable protective apparel. Provisions shall be made to facilitate personal hygiene at breaks and following daily operations.

7.15 Publications

The requirements specified in the following list of the requirements publications shall provide the basic safety program for this project:

1. Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities: NIOSH, 85-115.

2. Combe Fill South Landfill Superfund Site Remedial Design - Preliminary Design Report. O'Brien & Gere Engineers, Inc., July, 1989.

3. OSHA General Industry and Construction Standards: 29 CFR 1910 and 1926.

4. USEPA Standard Operating Safety Guides: November 1984.

5. ACGIH Threshold Limit Values and Biological Exposure Indices for 1990-1991.

6. Combe Fill South Landfill Superfund Site Remedial Construction - Volume 2A - Technical Specifications, O'Brien & Gere Engineers, Inc., February 1992.

7. Combe Fill South Landfill Superfund Site Remedial Construction - Volume 2B - Technical Specifications, O'Brien & Gere Engineers, Inc., February 1992.

8. Combe Fill South Landfill Superfund Site Remedial Construction - Contract Drawings, O'Brien & Gere Engineers, Inc., February 1992.

9. Combe Fill South Landfill Superfund Site Remedial Construction - Final Design Report, Vol. 1 of 3, O'Brien & Gere Engineers, Inc., 1993.

10. Combe Fill South Landfill Superfund Site Remedial Construction - Appendices Vol. 2 of 3, O'Brien & Gere Engineers, Inc., April 1991.

11. Combe Fill South Landfill Superfund Site Remedial Construction Design Report - Appendices 3 of, O'Brien & Gere Engineers, Inc., April 1991.

12. Combe Fill South Landfill Superfund Site Remedial Construction - Volume 3 - Site Data, O'Brien & Gere Engineers, Inc., February 1992.

SECTION 8 - PERMITTING

8.01 General

In order to implement the Remedial Design for the Combe Fill South Landfill, certain construction and operational permits are required. The purpose of this section is to identify the status of these permits and their requirements for the cover system, shallow groundwater collection and conveyance system, and the landfill gas collection and treatment system. The following subsections outline the information which has been addressed in the permit application submissions and, when available, the approxImate turnaround time associated with the review and approval process.

8.02 Soil Erosion and Sediment Control Plan Certification

Prior to the commencement of construction activities in which more than 5,000 square feet of surface area of land surface is disturbed, a Soil Erosion and Sediment Control Plan must be submitted to and certified by the local soil conservation district (SCD). In this case the SCD is the Morris County Soil Conservation District. This certification is a condition of development project approval by local municipalities. Pursuant to conversations with the Morris County SCD, the following forms must be submitted prior to certification:

1. Standard Application Form - Soil erosion and sediment control plan certification.

2. Site Plan - Bearing the seal of a Professional Engineer, delineating the 100 year flood plain, location of soil erosion and sediment control facilities, and drainage calculations

3. Soil erosion and sediment control plan description which includes identification of the disturbed land area, and planned control measures.

It was determined, in conjunction with the NJDEP Division of Hazardous Site Mitigation that this submission would most appropriately be submitted by the contractor selected for this project. This requirement has been incorporated into the contract specifications.

8.03 Air Quality Permit

Construction of any treatment or venting system which will contribute emissions, other than air or water, to the atmosphere requires a Permit to Construct, Install or Alter Control Apparatus as well as a certificate to operate which must be obtained from the NJDEP Division of Environmental Quality. Such a permit is required for the landfill gas collection system with control device (flare) to be installed during the landfill closure at the Combe Fill South Landfill. The forms which must be submitted include the application Forms VEM-003, VEM-004 and a Source Data Sheet - Flares.

Form VEM-003 specifies the applicant, location and type of system, reason for the current application and summarizes the stack information such as emission rates, temperatures and height above grade. Form VEM-004 Source Emissions and Source Data Form summarizes emission data, including control apparatus, air contaminant emission rates expected, source of air contaminants, and other information as applicable. Finally, the Source Data Sheet -Flares contains the expected type of flare to be used and summarizes technical information regarding the destruction efficiency, rates, velocity of emission and flame monitoring system.

Landfill gas will be collected via an active vent system, and gas condensate will be directed to the groundwater treatment system. Approximately 3040 standard cubic feet per minute (SCFM) of landfill gas will not be condensed and will be vented through a flare to combust organic fumes. The flare will be designed for a 99% destruction efficiency of organic fumes. No supplementary fuel is connected to the flare, at this time, other than fuel for pilot ignition. Air emission rates for methane, carbon monoxide, hydrogen sulfide, hydrogen chloride and sulfur dioxide have been estimated based upon the landfill gas analysis and the specified 99% destruction efficiency for the burner. Emission rates for these parameters are equal to or less than those specified by the Southern Coast Air Quality Management District - California (SCAQMD). The SCAQMD values were used as acceptable emission rates at the express direction of the NJDEP. Emission rates for nitrogen oxides and total suspended particulates were calculated based on the SCAQMD emission factors for these parameters. Again, these calculations were performed at the direction of the NJDEP through the permit review process.

An initial permit application submission was submitted to the NJDEP on July 26,1990, with a revised application submitted on January 8,1991 based upon comments received from the _ NJDEP on November 9,1990. A temporary certificate to operate is valid for 90 days, while a permanent certificate will be valid for five years.

This permit is currently pending with the NJDEP; Division of Environmental Quality. According to Mr. Rajesh Patel of this Division, the review is expected to be complete approximately in May 1991.

With regard to the ground water treatment system, neither the equalization tanks nor the ground water SBRs should require emissions controls for volatile organic compounds. The sum of maximum concentrations of volatile organic compounds found in the different ground water monitoring wells is 534 ug/L (see Table 5-1). For the design flow of 140,000 gallons per day and assuming that all VOCs volatilized from the system, the total VOC emissions would be approximately 0.6 pound per day. New Jersey regulations (N.J.A.C. 7:27-17) indicate that an air permit is not necessary for waste and water treatment equipment if the total concentration of volatile organic substances (VOS) does not exceed 3,500 ug/l and if each of the VOSs included in N.J.A.C. 7:27-17 does not exceed 100 ug/l. The listed compounds found in ground water at CFSL are below the 100 ug/l limit for permit requirements.

An exception to the N.J.A.C. 7:27-17 exemption for waste and water treatment equipment is air stripping equipment with capacities greater than 100,000 gpd. The definition of "air stripping equipment," provided in NJAC 7:27-8.1, means equipment used to transfer volatile organic substances from water into the atmosphere. Specific examples presented within the definition include packed columns and water spray equipment. Therefore, the exception for "air stripping equipment with a capacity greater than 100,000 gallons per day" (NJAC 7:27-8.2(a)15.ii) would not apply to the proposed treatment facility. For this reason, an air permit is not required for the ground water treatment facility.

8.04 Disruption of Solid Waste Permit

Prior to any construction or excavation activity on or in a closed existing solid waste land disposal area, an approval of such activities must first be obtained from the NJDEP Division of Solid Waste. The required application forms include:'9~!

1. NJDEP Standard Application Form CP- 1
2. NJDEP Solid Waste Supplement To Standard Application Form CP-1
3. Engineering plans and specifications which identify the area involved, final postdisruption grades, estimated volume of disruption, work timeframes, and nuisance control measures.

The Disruption of Solid Waste Permit Equivalent was issued by the Division of Solid Waste through a memo dated August 27, 1990.

8.05 Water Allocation Permit (Equalization)

Prior to the operation of any remediation system which will divert more than 100,000 gallons of water per day (70 gpm) from surface or ground waters for non-agricultural purposes, a permit must be filed with the NJDEP Division of Water Resources. This permit application is required for initial permits and includes the following:

1. NJDEP Standard Application Form CP- 1
2. NJDEP Form DWR-083 for Subsurface Waters

A Staff Report (Permit Equivalent) was received by O'Brien & Gere on February 22,1991. A NJDEP Memorandum revising the Staff Report was received by O'Brien & Gere on March 15, 1991.

The NJDEP Bureau of Water Allocation requires the completion of drilling permits for all wells or borings which encounter ground water prior to the commencement of drilling. Well permits are required specified in NJAC 7:14A-6.13. Permit applications are typically com pleted by the drilling company and signed by the party with overall responsibility for the well or boring.

8.06 Ground Water Dewatering Permit

After reviewing the requirements for Ground Water Dewatering Permits it was determined that no dewatering permit will be required for this project. This interpretation was provided by Helve Saarela, Environmental Engineer of the NJDEP Division of Water Resources, Bureau of Water Allocation, since the construction dewatering rates are not expected to exceed 100,000 gallons per day. This ruling regarding this permit is contained in the NJDEP Staff Report for the Water Allocation Permit, dated February 22, 1991.

8.07 Stream Encroachment Permit

Since the discharge outfall for the treatment facility is beyond 300 linear feet from the nearest stream and there is no construction anticipated within the stream, the Division of Coastal Resources has been requested, in writing, to provide an interpretation of the applicability of a Stream Encroachment Permit to this facility. On December 28, 1990, a letter requesting the applicability determination, accompanied by a site plan delineating streams and the discharge headwall, was forwarded to the NJDEP Division of Hazardous Site Mitigation. Subsequently, the

Division of Coastal Resources has agreed that a stream encroachment permit will not be required for the treatment plant outfall.

8.08 Freshwater Wetlands Permit

The Division of Coastal Resources has determined that this project will be covered by the Statewide General Permit Number 4 for freshwater wetlands. The form submitted for this permit was FW-1, Freshwater Wetlands Permit Application. This application was initially filed with the Division of Hazardous Site Mitigation on December 21, 1990, and revised at the NJDEP's request on March 1, 1991.

8.09 Discharge to Surface Water Permit

Prior to the construction or operation of a facility which discharges to the surface waters of New Jersey, a Discharge to Surface Water (DSW) Permit is required under the New Jersey Pollutant Discharge Elimination System (NJPDES) program. The forms which have been filed for this permit include:

1. EPA Application Form 1
2. EPA Application Form 2C
3. NJDEP Standard Application Form CP-1
4. NJDEP Supplemental Form WQM-001

These forms were filed with the Division of Hazardous Site Mitigation on August 16,1990.

SECTION 9 - TRAFFIC IMPACT

9.01 General

The installation of remedial facilities at the Combe Fill South will require that a large amount of construction traffic operate in the vicinity of the site. This Section presents a discussion of both the estimated quantity of traffic and the ability of site access to accommodate this traffic.

9.02 Traffic Quantity

As presented in Section 10, it is estimated that construction activities at Combe Fill South will require three years to complete. Traffic quantity will vary over this time period, with the greatest amount of traffic occurring during construction of the cover. It is currently estimated that it will be necessary to bring in excess of 700,000 cubic yards of material to the site prior to and during the time that the site is being capped. This amount includes material necessary for grading, and construction of the soil barrier layer, drainage layer, vegetative layer and topsoil layer. Assuming that trucks with a capacity of 15 cubic yards are used to transport the material, this represents in excess of 46,000 trucks arriving at the site during the period in which the cap is being constructed.

The peak truck arrival rate will occur during placement of the cap. Utilizing the schedule presented in Section 10 and estimated quantities for the various cap layers, the following delivery rates can be calculated:

Component	Total Estimated Construction Time	Total Estimated Quantity (CY)	Average Delivery Rate (CY/Month)
Soil Barrier Layer	7 Months	263,000	37,600
Drainage Layer	9 Months	121,000	13,500
Vegetative Layer	8.5 Months	181,000	21,300
Topsoil	4 Months	61,000	15,300

Recognizing that placement of these materials may proceed in parallel during some portions of construction, there may be a time, shown as a one month period on the estimated construction schedule that materials may be delivered at the rate of 87,700 cubic yards per month. Again assuming 22 days per month, eight hour days and the use of 15 cubic yard trucks, this equates to approximately 33 trucks per hour arriving at the site. Although it is recognized that there will be traffic associated with the delivery of other materials, the rate of 33 trucks per hour likely represents an upper limit to the rate of trucks arriving at the site. According to the anticipated construction schedule, this rate will occur for only a one month period. However, the arrival rate of 33 trucks per hour may cause concern with residents in the vicinity of the landfill as well as create difficulties with site operations. It is, therefore, likely that the contractor will modify the traffic arrival rate by working longer days, working more days per month and stockpiling material at the site during months in which placement of cap material is not occurring. As an example, if the contractor worked delivery material sixteen hours a day, six days a week during this peak period, the arrival rate is reduced to a more manageable 14 trucks per hour.

9.03 Site Accessibility

The Combe Fill South lies immediately to the north of Parker Road, a municipal road in Chester Township, Morris County, New Jersey. The Morris County Road Department was contacted to determine what, if any, load limits exist on Parker Road. The question was referred to the Chester Township Police Department. A representative of this agency indicated that there are no load limits for Parker Road. This representative indicated that the road is presently used by vehicles such as garbage trucks and trucks operated by construction companies located in the area. Approximately two miles to the northeast of the site, Parker Road intersects State Route 24 which runs generally east west. State Route 24 intersects U.S.Route 206 approximately two miles to the east of its intersection with Parker Road. U.S. Route 206 is a four lane, divided highway running in a north south direction. U.S. Route 206 intersects Interstate Route 80 approximately eight miles to the north of the intersection of State Route 24 and U.S. Route 206. U.S. Route 206 also intersects Interstate Route 78 approximately 11 miles to the south of the intersection of State Route 24 and U.S. Route 206. Both Interstate 80 and Interstate 78 are major east west arterials.

Access to the site from Parker Road will be provided by a twenty four foot wide access. The access road will consist of a 12 inch thick granular subbase course topped by a four inch thickness of asphalt concrete.

SECTION 10 - CONSTRUCTION SCHEDULE

10.01 General

Figure 10-1 presents an estimated schedule for construction of the remedial facilities at the Combe Fill South. It indicates that the total estimated time for construction will be on the order of three years.

The schedule was prepared assuming that construction would start in the month of April. It was assumed that one month would consist of 22 work days, each with a duration of eight hours. An allowance was incorporated for lost time associated with the use of personal protective equipment for work tasks under which this will be required.

10.02 Construction Sequence

Construction will be initiated with mobilization of equipment to the site and construction of ancillary facilities. These will include the main access road, site fencing, and decontamination facilities. Permits required by the Contractor for construction will be sought following the award of the bid and likely be finalized during the mobilization period. Concurrent with mobilization, off-site culverts required for site drainage may be installed. The total estimated time for these activities is two months.

At the conclusion of mobilization and associated activities, construction of the perimeter access road may be started. Following initiation of construction of the perimeter access road, gabion installation can be started along with refuse and site grading. Refuse and site grading may be conducted over the first winter period. It is estimated that installation of the perimeter access road may take three months, gabion installation may take four and a half months, and refuse and site grading may take eleven months. Concurrent with these activities, the gas extraction building can be constructed. Upon completion of the perimeter access road, the ground water collection system may be installed.

Work associated with construction of the ground water treatment facility can also be initiated after mobilization and associated activities are completed. It is estimated that the total time for construction of the ground water treatment facility will be approximately fifteen months, followed by a start-up period of approximately three months. The contractor will want to complete this facility as soon as possible in order to bring it on-line to aid in treating potentially contaminated water generated by construction activities. During the period prior to bringing the plant on-line, the contractor will be required to collect and handle construction water and contaminated water in accordance with the approved Construction Water Management Plan and the Contaminated Water Management Plan. (Contaminated water is water which has come into contact with chemicals utilized for decontamination.) Acceptable methods of construction water treatment include on-site treatment, off-site treatment, and reinjection into the landfill. Contaminated water must be drummed and disposed of off-site.

After the majority of the site has been graded, installation of the gas extraction wells may be started. These will be installed prior to installation of the soil barrier layer in order to minimize damage to this layer and provide a location for disposal of cuttings from the drilling process. It is estimated that the installation of the gas extraction wells may take four and a half months. Concurrent with installation of the gas extraction wells, wells associated with the effectiveness monitoring plan can be installed (See Section 12.)

As the installation of gas wells is completed in a given area, the soil barrier layer may be installed in that area, followed by installation of the soil drainage layer and associated drainage piping, and the underground gas piping. The eighteen inch vegetative protection layer may then be installed over the soil drainage layer. As shown on Figure 10-1, the soil barrier layer should be covered by the soil drainage and vegetative protection layers prior to the winter shutdown in order to limit damage from frost action.

When construction is resumed during the following spring, installation of the various components of the cover (soil barrier layer, geosynthetic liner,(where required), soil drainage layer, vegetative protection layer, and topsoil) will proceed. It should be noted that installation of the soil drainage layer, geosynthetic liner, vegetative protection layer, and topsoil is limited by the rate of placement of the soil barrier layer. The total estimated time for placement of the soil barrier layer is seven months, extending over two construction seasons. Topsoil must be seeded prior to October in order to allow time for seed germination, and thus topsoil and seeding occurs during two construction seasons.

As the placement of topsoil is completed in a given area of the site, above ground piping associated with the gas extraction system may be installed. When this is completed, the extraction system may begin operation thus completing remedial construction associated with the cap and gas extraction system for the Combe Fill South.

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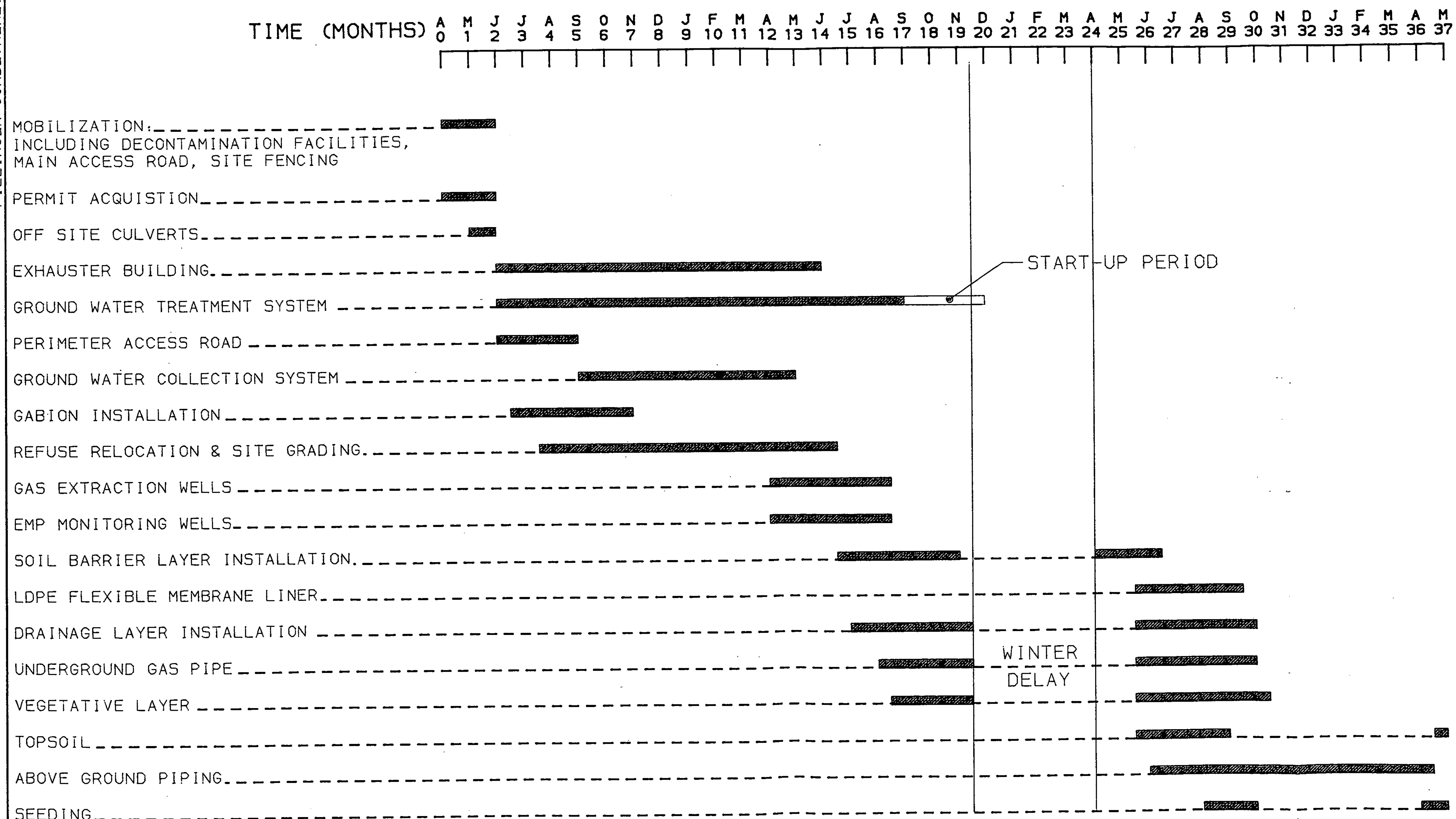
COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF ENVIROMENTAL PROTECTION
ANTICIPATED CONSTRUCTION SCHEDULE



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SECTION 11 - CONSTRUCTION COST ESTIMATE

The total estimated construction cost, prepared based on the final design, is \$49,676,990. Documentation associated with this estimate follows as Tables 11-1 and 11-2. Table 11-1 is the price schedule included in Volume 1 - Bid Documents of the Specifications. Table 11-2 provides documentation of the estimated construction cost. This estimate includes construction of the site access roads, cap, gas venting system, and ground water collection and treatment system. The estimate also includes costs for health and safety requirements during construction, equipment decontamination, mobilization/demobilization and two years of operation and maintenance following construction.

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price: Words	Unit Bid Price: Figures Dollars	Unit Bid Price: Figures Cts	Item Total Bid Price: Dollars	Item Total Bid Price: Cts
1.	Performance and Payment Bonds	L.S.	Job	Seven Hundred Twenty Thousand Dollars and Zero Cents	720,000	00	720,000	00
2.	Mobilization/Demobilization	L.S.	Job	Nine Hundred Sixty Thousand Dollars and Zero Cents	960,000	00	960,000	00
3.	Operation and Maintenance of Temporary Facilities	L.S.	Job	Fifty Thousand Dollars and Zero Cents	$ 50,000	00	$ 50,000	00
4.	Cash Allowance for Telephone, Electric and Gas Service	L.S.	Job	Seventy Thousand Dollars and Zero Cents	$ 70,000	00	$ 70,000	00
5.	On-Site Geotechnical Testing Laboratory	L.S.	Job	Two Hundred Fifty Two Thousand Three Hundred Dollars and Zero Cents	252,300	00	252,300	00
6.	Site Clearing and Grubbing	L.S.	Job	Four Hundred Twenty Five Thousand, Two Hundred Fifty Dollars and Zero Cents	$ 425,250	00	$ 425,250	00
7.	Construction Water Management and Disposal	L.S.	Job	Two Hundred Sixty Thousand Dollars and Zero Cents	$ 260,000	00	$ 260,000	00
8.	Earthwork – Fill/Refuse Relocation	C.Y.	200,000	Thirty Two Dollars and Forty Cents	$ 32	40	$ 6,480,000	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Unit Bid Price Figures Cts	Item Total Bid Price Dollars	Item Total Bid Price Cts
9.	Off-Site Embankment Material	C.Y.	130,000	Twenty Four Dollars and Zero Cents	$ 24	00	$3,120,000	00
10.	Soil Barrier Layer Test Section	L.S.	Job	Fifty Thousand Dollars and Zero Cents	$ 50,000	00	$ 50,000	00
11.	Soil Barrier Layer: Natural Clay Option or Bentonite Amended Option (Cross Out The Alternate Not Bid)	C.Y.	201,476	Sixty One Dollars and Seventy Five Cents	$ 61	75	$12,441,143	00
12.	Flexible Membrane Cover	S.F.	1,140,025	Zero Dollars and Sixty Cents	$ 0	60	684,015	00
13.	Geotextile Filter	S.F.	4,510,800	Zero Dollars and Thirty Cents	$ 0	30	$ 1,353,240	00
14.	Drainage Layer	C.Y.	100,738	Twenty Four Dollars and Zero Cents	$ 24	00	$ 2,417,712	00
15.	Vegetative Layer	C.Y.	151,107	Twenty Four Dollars and Zero Cents	$ 24	00	$ 3,640,920	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
16.	Cap Side Slope Diversion Ditches	L.F.	13,760	Ten Dollars and Zero Cents	$ 10	00	$ 137,600	00
17.	Cap Drainage Ditches	L.F.	3,638	Nineteen Dollars and Seventy Nine Cents	$ 19	79	71,996	02
18.	Topsoil	C.Y.	50,379	Thirty Dollars and Zero Cents	$ 30	00	1,511,370	00
19.	Seeding	Acres	63	Two Thousand One Hundred and Ten Dollars and Zero Cents	$ 2,110	00	$ 132,930	00
20.	Gabion Wall	C.Y.	4,850	One Hundred Thirty Four Dollars and Forty Six Cents	$ 134	46	$ 625,131	00
21.	Polyvinyl Chloride(PVC) Pipe 4 Inch Diameter							
21A	Perforated PVC Pipe	L.F.	14,160	Seventeen Dollars and Ninety Three Cents	$ 17	93	$ 253,888	80
21B	Solid PVC Pipe	L.F.	680	One Dollar and Zero Cents	$ 1	00	$ 680	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
22.	Cap Drainage Vaults	Each	3	Two Thousand Eight Hundred and Eight Dollars and Zero Cents	$ 2,808	00	$ 8,424	00
23.	Road Grading:							
23A	24 foot wide main access road	L.F.	1,586	Two Dollars and Eighty Four Cents	$ 2	84	$ 4,504	24
23B	12 foot wide perimeter road	L.F.	7,000	One Dollar and Ninety Two Cents	$ 1	92	$ 13,415	00
23C	18 foot wide driveways and Parking Lot	S.Y.	1,295	Two Dollars and Zero Cents	$ 2	00	$ 2,590	00
24.	Perimeter Access Road Material (Dense Graded Aggregate)	C.Y.	3,300	Forty Eight Dollars and Sixty Cents	$ 48	60	$ 160,380	00
25.	Granular Subbase for Paved Access Road (Dense Graded Aggregate)	C.Y.	2,350	Thirty Nine Dollars and Zero Cents	$ 39	00	$ 91,650	00
26.	Bituminous Paving:							
26A	Bituminous Concrete Base Course: Mix I–1	C.Y.	270	Eighty Eight Dollars and Zero Cents	$ 88	00	$ 23,760	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
26B	Bituminous Concrete Surface Course: Mix 1-3	C.Y.	135	Ninety Two Dollars and Zero Cents	$ 92	00	$ 12,420	00
26C	Bituminous Concrete Surface Course: Mix I-3	C.Y.	135	Ninety Six Dollars and Zero Cents	$ 96	00	$ 12,960	00
27.	Temporary Repairs to Parker Road	S.Y.	1,000	Five Dollars and Zero Cents	$ 5	00	$ 5,000	00
28.	Permanent Repairs to Parker Road	S.Y.	5,000	Nine Dollars and Zero Cents	$ 9	00	$ 45,000	00
29.	Gas Extraction Well (Base depth of 30 feet)	Each	66	Six Thousand Three Hundred and Forty Five Dollars and Zero Cents	$ 6,345	00	$ 418,770	00
30.	Add or Deduct per VLF of Gas Extraction Wells	V.L.F.	+600	Two Hundred Sixteen Dollars and Zero Cents	$ 216	00	$ 129,600	00

Bidder

COMBE FILL SOUTH LANDFILL

PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
31.	Gas Header Piping and Fittings: Below Grade Piping:							
31A	4 inch Schedule 40 PVC Pipe	L.F.	5,410	Eight Dollars and Zero Cents	$ 8	00	$ 41,120	00
31B	6 inch Schedule 40 PVC Pipe	L.F.	2,975	Twelve Dollars and Zero Cents	$ 12	00	$ 35,700	00
31C	8 inch Schedule 40 PVC Pipe	L.F.	7,135	Eighteen Dollars and Zero Cents	$ 18	00	$ 128,430	00
	Above Grade Piping:							
31D	4 inch Fiberglass Reinforced Epoxy Resin Pipe	L.F.	2,665	Twenty Five Dollars and Zero Cents	$ 25	00	$ 66,625	00
31E	6 inch Fiberglass Reinforced Epoxy Resin Pipe	L.F.	1,365	Thirty Five Dollars and Zero Cents	$ 35	00	$ 47,775	00
31F	8 inch Fiberglass Reinforced Epoxy Resin Pipe	L.F.	550	Fifty Five Dollars and Zero Cents	$ 55	00	$ 30,250	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
31G	Gas System Header Accessories	L.S.	Job	One Hundred Sixty Five Thousand Seven Hundred Eighty One Dollars and Zero Cents	$ 165,781	00	$ 165,781	00
32.	Condensate Collection System	L.S.	Job	Three Hundred Fourteen Thousand Three Hundred Thirty Five Dollars and Zero Cents	$ 314,335	00	$ 314,335	00
33.	Landfill Gas Treatment System	L.S.	Job	Seven Hundred Seventy Nine Thousand Six Hundred Twenty Dollars and Zero Cents	$ 779,620	00	$ 779,620	00
34.	Reinforced Concrete Pipe:							
34A	12 inch diameter	L.F.	100	Thirty Two Dollars and Zero Cents	$ 32	00	$ 3,200	00
34B	15 inch diameter	L.F.	215	Thirty Four Dollars and Zero Cents	$ 34	00	$ 7,310	00
34C	18 inch diameter	L.F.	55	Forty Two Dollars and Zero Cents	$ 42	00	$ 2,310	00
34D	21 inch diameter	L.F.	105	Forty Six Dollars and Zero Cents	$ 46	00	$ 4,830	00
34E	24 inch diameter	L.F.	50	Fifty Dollars and Zero Cents	$ 50	00	$ 2,500	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
34F	30 inch diameter	L.F.	25	Fifty Eight Dollars and Zero Cents	$ 58	00	$ 1,450	00
34G	36 inch diameter	L.F.	248	Seventy Nine Dollars and Zero Cents	$ 79	00	$ 19,592	00
35.	Reinforced Concrete Headwalls	Each	16	Two Thousand Two Hundred Seventy Dollars and Zero Cents	$ 2,270	00	$ 36,320	00
36.	Storm Manholes							
36A	4 foot Diameter Storm Manholes	Each	3	Two Thousand Five Hundred Sixty Dollars and Zero Cents	$ 2,560	00	$ 7,680	00
36B	5 foot Diameter Storm Manholes	Each	1	Three Thousand Four Hundred Fifty Six Dollars and Zero Cents	$ 3,456	00	$ 3,456	00
37.	Rip-Rap							
37A	Rip-Rap Lighter than 100 lbs.	C.Y.	5,900	Seventy Dollars and Zero Cents	$ 70	00	$ 413,000	00
37B	Rip-Rap Heavier than 100 lbs.	C.Y.	2,300	Seventy Dollars and Zero Cents	$ 70	00	$ 161,000	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
37C	Gabion Matresses	C.Y.	100	One Hundred Fifty Dollars and Zero Cents	$ 150	00	$ 15,000	00
37D	Rip-Rap Bedding	C.Y.	4,200	Fifty Five Dollars and Zero Cents	$ 55	00	$ 231,000	00
38.	Select Fill							
38A	Type A	C.Y.	1,000	Forty Dollars and Zero Cents	$ 40	00	$ 40,000	00
38B	Type B	C.Y.	800	Forty Dollars and Zero Cents	$ 40	00	$ 32,000	00
38C	Type C	C.Y.	500	Forty Dollars and Zero Cents	$ 40	00	$ 20,000	00
38D	Type D	C.Y.	1,900	Forty Dollars and Zero Cents	$ 40	00	$ 76,000	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
38E	Type E	C.Y.	200	Thirty Five Dollars and Zero Cents	$ 35	00	$ 7,000	00
38F	Type F	C.Y.	1,200	Forty Dollars and Zero Cents	$ 40	00	$ 48,000	00
38G	Type G	C.Y.	200	Forty Five Dollars and Zero Cents	$ 45	00	$ 9,000	00
38H	Type H	C.Y.	400	Forty Five Dollars and Zero Cents	$ 45	00	$ 18,000	00
38I	Type I	C.Y.	100	Forty Five Dollars and Zero Cents	$ 45	00	$ 4,500	00
39.	Concrete	C.Y.	50	Two Hundred Twenty Five Dollars and Zero Cents	$ 225	00	$ 11,250	00
40.	Detention Basins	L.S.	Job	Eight Hundred Seventy Thousand Dollars and Zero Cents	$ 870,000	00	$ 870,000	00
41.	Shallow Ground Water Recovery Wells (Base depth of 40 feet)	Each	19	Sixteen Thousand Eight Hundred Seventy Five Dollars and Zero Cents	$ 16,875	00	$ 320,625	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
42.	Add or Deduct per VLF of Shallow Ground Water Recovery Well	V.L.F	+150	Three Hundred Twenty Four Dollars and Zero Cents	$ 324	00	$ 48,600	00
43.	Shallow Ground Water Collection System	L.S.	Job	Seven Hundred Fifty One Thousand Six Hundred Fifty Dollars and Zero Cents	$ 751,650	00	$ 751,650	00
44.	Ground Water Treatment System	L.S.	Job	Four Million Seventeen Thousand Seven Hundred Twenty Six Dollars and Zero Cent	$ 4,017,726	00	$ 4,017,726	00
45.	Effectiveness Monitoring Wells							
45A	2-inch diameter PVC monitor wells (Base depth of 40 feet)	Each	18	Four Thousand Eight Hundred Sixty Dollars and Zero Cents	$ 4,860	00	$ 87,480	00
45B	4-inch diameter PVC monitor wells (Base depth of 35 feet)	Each	11	Four Thousand Three Hundred Eighty Seven Dollars and Fifty Five Cents	$ 4,387	55	$ 48,263	05
45C	6-inch diameter PVC monitor wells (Base depth of 70 feet)	Each	9	Twelve Thousand Two Hundred Seventy One Dollars and Fifty Six Cents	$ 12,271	56	$ 110,444	04
45D	6-inch diameter steel bedrock monitor wells (Base depth of 75 feet)	Each	6	Ten Thousand Six Hundred Seventeen Dollars and Eight Three Cents	$ 10,617	83	$ 63,706	98
45E	6-inch diameter steel off-site bedrock monitor wells (Base depth of 100 feet)	Each	3	Fourteen Thousand Three Hundred Dollars and Zero Cents	$ 14,300	00	$ 42,900	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Figures Dollars	Figures Cts	Item Total Bid Price Dollars	Item Total Bid Price Cts
45F	6-inch diameter steel off-site bedrock monitor wells (Base depth of 150 feet)	Each	3	Nineteen Thousand Five Hundred Sixty Five Dollars and Zero Cents	$ 19,565	00	$ 58,695	00
45G	6-inch diameter steel off-site bedrock monitor wells (Base depth of 200 feet)	Each	3	Twenty Five Thousand Three Hundred Fifteen Dollars and Zero Cents	$ 25,315	00	$ 75,945	00
46.	Add or Deduct per VLF of Effectiveness Monitoring System							
46A	2-inch diameter PVC monitor wells	V.L.F	+150	One Hundred Twenty One Dollars and Fifty Cents	$ 121	50	$ 18,225	00
46B	4-inch diameter PVC monitor wells	V.L.F	+100	One Hundred Twenty Eight Dollars and Twenty Five Cents	$ 128	25	$ 12,825	00
46C	6-inch diameter PVC monitor wells	V.L.F	+150	One Hundred Seventy Five Dollars and Fifty Cents	$ 175	50	$ 26,325	00
46D	6-inch diameter steel bedrock monitor wells	V.L.F	+100	One Hundred Forty One Dollars and Seventy Five Cents	$ 141	75	$ 14,175	00
46E	6-inch diameter steel off-site bedrock monitor wells	V.L.F	+250	One Hundred and Five Dollars and Zero Cents	$ 105	00	$ 26,250	00

Bidder

COMBE FILL SOUTH LANDFILL

PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
47.	Grouting Existing Monitoring Wells & Borehole Abandonment							
47A	Grouting Existing Monitoring Wells	V.L.F	1,500	Fourteen Dollars and Zero Cents	$ 14	00	$ 21,000	00
47B	Borehole Abandonment	V.L.F	500	Fourteen Dollars and Zero Cents	$ 14	00	$ 7,000	00
48.	Erosion and Sediment Control	L.S.	Job	Three Hundred Fifteen Thousand Dollars and Zero Cents	$ 315,000	00	$ 315,000	00
49.	Chain Link Fence							
49A	Chain Link Fence Installation	L.F.	8,900	Nineteen Dollars and Ninety One Cents	$ 19	91	$ 177,199	00
49B	Chain Link Fence Grounding	L.S.	Job	Two Thousand Dollars and Zero Cents	$ 2,000	00	$ 2,000	00
50.	Decontamination Area and Facilites	L.S.	Job	Sixty Four Thousand Three Hundred Ten Dollars and Zero Cents	$ 64,310	00	$ 64,310	00
51.	Air Monitoring Plan							
51A	Air Monitoring Plan	L.S.	Job	Twenty Thousand Dollars and Zero Cents	$ 20,000	00	$ 20,000	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
51B	Additional Testing of Sorbent Tubes	Each	100	One Hundred Fifty Dollars and Zero Cents	$ 150	00	$ 15,000	00
52.	Dust Migration Control Plan	L.S.	Job	Seventy Four Thousand Dollars and Zero Cents	$ 74,000	00	$ 74,000	00
53.	Environmental Pollution Control Plan Development	L.S.	Job	Ten Thousand Dollars and Zero Cents	$ 10,000	00	$ 10,000	00
54.	Spill and Discharge Control Plan Development	L.S.	Job	Thirty Thousand Dollars and Zero Cents	$ 30,000	00	$ 30,000	00
55.	Quality Control Plan Development	L.S.	Job	One Hundred Sixty Four Thousand Dollars and Zero Cents	$ 164,000	00	$164,000	00
56.	Security Plan	L.S.	Job	Two Hundred Fifty Thousand Dollars and Zero Cents	$ 250,000	00	$ 250,000	00
57.	Health and Safety Plan	L.S.	Job	One Hundred Seventy Four Thousand Dollars and Zero Cents	$ 174,000	00	$ 174,000	00
58.	Drum Removal	Each	100	One Thousand Dollars and Zero Cents	$ 1,000	00	$ 100,000	00

Bidder

COMBE FILL SOUTH LANDFILL
PRICE SCHEDULE

Item No.	Item	Unit	Estimated Quantity	Unit Bid Price Words	Unit Bid Price Figures Dollars	Cts	Item Total Bid Price Dollars	Cts
59.	Test Pit Excavation & Backfilling	Each	25	Seven Hundred Forty Two Dollars and Fifty Two Cents	$ 742	52	$ 18,563	00
60.	Erosion Control Matting	S.Y.	11,000	Five Dollars and Zero Cents	$ 5	00	$ 55,000	00
61.	Operation and Maintenance – First Year	L.S.	Job	One Million One Hundred Seventy Seven Thousand, Seven Hundred Dollars and Zero Cents	$ 1,177,700	00	$ 1,177,700	00
62.	Operation and Maintenance – Second Year	Month	12	Eighty Four Thousand Two Hundred Twenty Five and Zero Cents	$ 84,225	00	$ 1,010,700	00
Total Bid Price in Words				Forty Nine Million Six Hundred Seventy Six Thousand, Nine Hundred Ninety Dollars and Zero Cents	Total Bid Price (Figures)		$ 49,676,990.00	

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
1. Performance & Payment Bonds 1.5% of subtotal	—	LS	—	$719,954	D	$719,954
2. Mobilization/Demobilization 2.0% of subtotal	—	LS	—	$959,939	D	$959,939
3. Operation & Maintenance of Temporary Facilities	—	LS	—	$50,000	D	$50,000
4. Cash Allowance for Telephone, Electric & Gas Service	—	LS	—	$70,000	D	$70,000
5. On-Site Geotechnical Testing Laboratory						
1. Trailer	—	LS	—	$15,500	D	$15,500
2. Lab. Equipment	—	LS	—	$100,000	D	$100,000
3. Disposable Lab. Supplies	36	MO	$500	$18,000	D	$18,000
4. Lab. Technician	36	MO	$3,300	$118,800	D	$118,800
		Item 5 Total :		$252,300		
6. Site Clearing & Grubbing	70	AC	$4,500	$315,000	C	$425,250
7. Construction Water Management and Disposal						
1. Plan Development	—	LS	—	$10,000	D	$10,000
2. Implementation	25	MO	$10,000	$250,000	D	$250,000
8. Earthwork – Fill/Refuse Relocation	200,000	CY	$24	$4,800,000	C	$6,480,000
9. Off-Site Embankment Material	130,000	CY	$24	$3,120,000	D	$3,120,000
10. Soil Barrier Layer Test Section	—	LS	—	$50,000	D	$50,000

Note: 1.) Items involving work requiring level C protection assume additional 35% mark-up for productivity losses.
2.) Items involving work requiring level D+ protection assume additional 13% mark-up for productivity losses.
3.) Items involving work requiring level D protection assume no additional mark-up for productivity losses.
4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
11. Soil Barrier Layer						
1. Soil Bentonite & Mixing	201,476	CY	$50	$10,073,800	D	$10,073,800
2. Placement of Lower 1 foot	100,738	CY	$10	$1,007,380	C	$1,359,963
3. Placement of Upper 1 foot	100,738	CY	$10	$1,007,380	D	$1,007,380
12. Flexible Membrane Cover	1,140,025	SF	$0.60	$684,015	D	$684,015
13. Geotextile Filter	4,510,800	SF	$0.30	$1,353,240	D	$1,353,240
14. Drainage Layer	100,738	CY	$24	$2,417,712	D	$2,417,712
15. Vegetative Layer	151,705	CY	$24	$3,640,920	D	$3,640,920
Cap Side Slope Diversion Ditch	13,760	LF	$10	$137,600	D	$137,600
17. Cap Drainage Ditches (Vegetative Layer Material)	3,000	CY	$24	$72,000	D	$72,000
18. Topsoil	50,379	CY	$30	$1,511,370	D	$1,511,370
19. Seeding	63	AC	$2,110	$132,930	D	$132,930
20. Gabion Wall (6' High)	5,820	LF	$83	$483,060	C	$652,131
21. A. Perforated PVC Drainage Pipe						
1. 4" Perforated Pipe	14,160	LF	$1	$14,160	D	$14,160
2. Pea Stone	4,700	CY	$51	$239,700	D	$239,700
B. Solid PVC Pipe	680	LF	$1	$680	D	$680
22. Cap Drainage Vaults	3	EA	$2,080	$6,240	C	$8,424

Note: 1.) Items involving work requiring level C protection assume additional 35% mark-up for productivity losses.
2.) Items involving work requiring level D+ protection assume additional 13% mark-up for productivity losses.
3.) Items involving work requiring level D protection assume no additional mark-up for productivity losses.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
23. A. 24 foot wide main access road						
1. Grading	4,230	SY	$0.90	$3,807	D	$3,807
2. Ditching	3,170	LF	$0.22	$697	D	$697
B. 12 foot wide perimeter access road						
1. Grading	9,330	LF	$0.90	$8,397	C	$11,336
2. Ditching	7,000	LF	$0.22	$1,540	C	$2,079
C. 18 foot wide driveways and parking lot	1,295	SY	$2	$2,590	D	$2,590
24. Perimeter Access Road Material	3,300	CY	$36	$118,800	C	$160,380
25. Granular Subbase for Paved Access Road	2,350	CY	$39	$91,650	D	$91,650
3. A. Bituminous Concrete Base Course: Mix I–1	540	TONS	$44	$23,760	D	$23,760
B. Bituminous Concrete Binder Course: Mix I–4	270	TONS	$46	$12,420	D	$12,420
C. Bituminous Concrete Surface Course: Mix I–3	270	TONS	$48	$12,960	D	$12,960
27. Temporary Repairs to Parker Road (Assume 2" binder course)	1,000	SY	$5	$5,000	D	$5,000
28. Permanent Repairs to Parker Road (Assume 2" binder course & 1" top course)	5,000	SY	$9	$45,000	D	$45,000
29. Gas Extraction Well (Base depth of 30 feet)	66	EA	$4,700	$310,200	C	$418,770
30. Add or Deduct per VLF of Gas Extraction Well	600	VLF	$160	$96,000	C	$129,600

Note: 1.) Items involving work requiring level C protection assume additional 35% mark–up for productivity losses.
2.) Items involving work requiring level D+ protection assume additional 13% mark–up for productivity losses.
3.) Items involving work requiring level D protection assume no additional mark–up for productivity losses.
4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTIO COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
31. Gas Header Piping and Fittings						
Below Grade Piping :						
A. 4 inch Schedule 40 PVC Pipe	5,140	LF	$8	$41,120	D	$41,120
B. 6 inch Schedule 40 PVC Pipe	2,975	LF	$12	$35,700	D	$35,700
C. 8 inch Schedule 40 PVC Pipe	7,135	LF	$18	$128,430	D	$128,430
Above Grade Piping :						
D. 4 inch Fiberglass Reinforced Epoxy Resin Pipe	2,665	LF	$25	$66,625	D	$66,625
E. 6 inch Fiberglass Reinforced Epoxy Resin Pipe	1,365	LF	$35	$47,775	D	$47,775
F. 8 inch Fiberglass Reinforced Epoxy Resin Pipe	550	LF	$55	$30,250	D	$30,250
s Header System Accessories						
1. Concrete Anchor Blocks	18	EA	$225	$4,050	C	$5,468
2. Pipe Supports	275	EA	$200	$55,000	D+	$62,150
3. Gas Piping Access Manholes	5	EA	$1,950	$9,750	C	$13,163
4. Gas Header Fittings	—	LS	—	$60,000	D	$60,000
5. Pipe Fittings	—	LS	—	$25,000	D	$25,000
		Item 31 Total :		$515,680		

Note: 1.) Items involving work requiring level C protection assume additional 35% mark-up for productivity losses.
2.) Items involving work requiring level D+ protection assume additional 13% mark-up for productivity losses.
) Items involving work requiring level D protection assume no additional mark-up for productivity losses.
4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTIO COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
2. Condensate Collection System						
1. Collection Manholes	3	EA	$2,100	$6,300	C	$8,505
2. Piping Manholes	2	EA	$2,100	$4,200	C	$5,670
3. 4" HDPE Gravity Drain Line	1450	LF	$15	$21,750	D	$21,750
4. 3" HDPE Force Main	2,280	LF	$12	$27,360	D	$27,360
5. 8" Ductile Iron Tank Drain	520	LF	$31	$16,120	D	$16,120
6. Multiple Gas Header Vault	1	EA	$10,500	$10,500	D	$10,500
7. Miscellaneous Fittings	—	LS	—	$20,000	D	$20,000
8. Condensate Pump Stations						
a. Manholes	2	EA	$7,700	$15,400	C	$20,790
b. Valve Boxes	2	EA	$3,200	$6,400	C	$8,640
c. Double Leaf Access Doors	2	EA	$1,000	$2,000	D	$2,000
d. Double Leaf Access Doors	2	LF	$1,500	$3,000	D	$3,000
e. Miscellaneous Valves	—	LS	—	$60,000	D	$60,000
f. Miscellaneous Piping	—	LS	—	$3,000	D	$3,000
g. Miscellaneous Fittings	—	LS	—	$50,000	D	$50,000
h. Duplex Submersible Pumps	2	EA	$16,000	$32,000	D	$32,000
i. Electrical	—	LS	—	$25,000	D	$25,000
		Item 32 Total :		$314,335		

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4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
33. Landfill Gas Treatment System						
1. Site Work	—	LS	—	$10,000	D	$10,000
2. Gas Extraction Building						
Superstructure:						
A. Columns and Beams	2000	SF	$17.00	$34,000	D	$34,000
B. Roof (Metal Deck)	2000	SF	$12.00	$24,000	D	$24,000
C. Walls (Metal Siding)	2000	SF	$18.00	$36,000	D	$36,000
D. Roof Specialties (OPNGS)	2000	SF	$2.00	$4,000	D	$4,000
E. Slab on Grade	1750	SF	$8.00	$14,000	D	$14,000
Interior:						
A. Masonry Block	450	SF	$11.00	$4,950	D	$4,950
B. Secondary Containment Cell	20	CY	$420.00	$8,400	D	$8,400
C. Ladders and Platforms	—	LS	—	$6,600	D	$6,600
D. Misc. Metal Fabrications	—	LS	—	$1,200	D	$1,200
Exterior:						
A. Overhead Doors	1	EA	$3,600	$3,600	D	$3,600
B. Man Doors	3	EA	$1,200	$3,600	D	$3,600
Foundations	—	LS	—	$24,000	D	$24,000
Process System:						
A. NaOH Tank	—	LS	—	$11,450	D	$11,450
B. PAC Tank	—	LS	—	$5,725	D	$5,725
C. Metering Pumps(P-114,115,116)	—	LS	—	$4,645	D	$4,645
D. Debagger	—	LS	—	$10,150	D	$10,150
3. Sediment/Condensate Traps	3	EA	$4,200	$12,600	D	$12,600
4. Automatic Condensate Traps	3	EA	$600	$1,800	D	$1,800
5. Flame Arrestors	1	EA	$4,500	$4,500	D	$4,500
6. Landfill Gas Exhausters	4	EA	$10,000	$40,000	D	$40,000
7. Electrical:						
A. Motor Control Center	1	EA	$20,000	$20,000	D	$20,000
B. Distribution	—	LS	—	$20,000	D	$20,000
C. Lighting	—	LS	—	$14,400	D	$14,400
D. Gas Detection	—	LS	—	$12,000	D	$12,000
E. Conduit and Wire	—	LS	—	$15,000	D	$15,000
F. Ground Grid	500	LF	$12	$6,000	D	$6,000

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3.) Items involving work requiring level D protection assume no additional mark-up for productivity losses.
4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
8. Fire Suppression	—	LS	—	$12,000	D	$12,000
9. Exhauster	1	EA	$6,000	$6,000	D	$6,000
10. Heating/Ventilating:						
A. Electric Heaters	4	EA	$6,000	$24,000	D	$24,000
B. Misc. Blowers	1	EA	$2,400	$2,400	D	$2,400
C. Ductwork	—	LS	—	$3,000	D	$3,000
11. Temp. Controls	—	LS	—	$3,600	D	$3,600
12. Piping, Valves	—	LS	—	$5,000	D	$5,000
13. Gas Flares:						
A. Gas Flares with Controls	1	EA		$360,000	D	$360,000
B. Piping – Sch. 40 Steel 12" dia.	50	LF	$100	$5,000	D	$5,000
C. Misc. Fittings	—	LS	—	$6,000	D	$6,000
		Item 33 Total :		$779,620		
34. Reinforced Concrete Pipe						
A. 12 inch Diameter	100	LF	$32	$3,200	D	$3,200
B. 15 inch Diameter	215	LF	$34	$7,310	D	$7,310
C. 18 inch Diameter	55	LF	$42	$2,310	D	$2,310
D. 21 inch Diameter	105	LF	$46	$4,830	D	$4,830
E. 24 inch Diameter	50	LF	$50	$2,500	D	$2,500
F. 30 inch Diameter	25	LF	$58	$1,450	D	$1,450
G. 36 inch Diameter	248	LF	$79	$19,592	D	$19,592
		Item 34 Total :		$41,192		
35. Reinforced Concrete Headwalls	16	EA	$2,270	$36,320	D	$36,320
36. Storm Manholes						
A. 5 foot Diameter Storm Manholes	3	EA	$2,560	$7,680	D	$7,680
B. 5 foot Diameter Cap Drainage Manhole	1	EA	$2,560	$2,560	C	$3,456

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4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
37. Rip-Rap						
A. Rip-Rap Lighter Than 100 lbs.	5900	CY	$70	$413,000	D	$413,000
B. Rip-Rap Heaver Than 100 lbs.	2300	CY	$70	$161,000	D	$161,000
C. Gabion Matresses	100	CY	$150	$15,000	D	$15,000
D. Rip-Rap Bedding	4200	CY	$55	$231,000	D	$231,000
		Item 37 Total :		$820,000		
38. Select Fill						
A. Type A	1,000	CY	$40	$40,000	D	$40,000
B. Type B	800	CY	$40	$32,000	D	$32,000
C. Type C	500	CY	$40	$20,000	D	$20,000
D. Type D	1,900	CY	$40	$76,000	D	$76,000
E. Type E	200	CY	$35	$7,000	D	$7,000
F. Type F	1,200	CY	$40	$48,000	D	$48,000
G. Type G	200	CY	$45	$9,000	D	$9,000
H. Type H	400	CY	$45	$18,000	D	$18,000
I. Type I	100	CY	$45	$4,500	D	$4,500
		Item 38 Total :		$254,500		
39. Concrete	50	CY	$225	$11,250	D	$11,250
40. Detention Basins						
1. Construction	—	LS	—	$600,000	D	$600,000
2. Maintenance	36	MO	$7,500	$270,000	D	$270,000
41. Shallow Groundwater Recovery Well (Base depth of 40 feet)	19	EA	$12,500	$237,500	C	$320,625
42. Add or Deduct per VLF of Shallow Groundwater Recovery Well	150	VLF	$240	$36,000	C	$48,600

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4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
43. Shallow Ground Water Recovery System						
1. Submersible Pumps	19	EA	$16,000	$304,000	D	$304,000
2. 6 inch diameter HDPE Force Main	2,400	LF	$15	$36,000	D	$36,000
3. 8 inch diameter HDPE Force Main	4200	LF	$20	$84,000	D	$84,000
4. Force Main Drains	4	EA	$2,000	$8,000	D	$8,000
5. Trenching and Backfilling	6,600	LF	$4	$26,400	D	$26,400
6. Concrete Vaults	19	LF	$5,000	$95,000	C	$128,250
7. Electrical						
a. Incoming Service Charge	—	LS	—	$10,000	D	$10,000
b. Riser Pole with Hardware	4	EA	$3,000	$12,000	D	$12,000
c. Metering Equipment	—	LS	—	$9,000	D	$9,000
d. Distribution Switchgear	1	EA	$25,000	$25,000	D	$25,000
e. Underground Distribution (conduits)	7000	LF	$7	$49,000	D	$49,000
f. Distribution Control	—	LS	—	$25,000	D	$25,000
8. Spare Parts	—	LS	—	$5,000	D	$5,000
9. System Start-up	—	LS	—	$30,000	D	$30,000
		Item 43 Total :		$751,650		
44. Groundwater Treatment System						
1. Site Work	—	LS	—	$30,000	D	$30,000
2. Outside Piping and Utilities						
A. Outfall Sewer	700	LF	$50	$35,000	D	$35,000
B. Outside Piping	—	LS	—	$70,000	D	$70,000
C. Gas Line	1000	LF	$30	$30,000	D	$30,000
D. Waterline	1000	LF	$35	$35,000	D	$35,000
E. 4" PVC Telephone Duct	1000	LF	$8	$8,000	D	$8,000
F. Electrical Duct Bank	—	LS	—	$18,000	D	$18,000
3. Process Equipment Building						
Superstructure:						
A. Columns & Beams	3000	SF	$17	$51,000	D	$51,000
B. Roof (Metal Deck)	4600	SF	$12	$55,200	D	$55,200
C. Walls (Metal Siding)	7500	SF	$12	$90,000	D	$90,000
D. Roof Specialties	100	SF	$12	$1,200	D	$1,200
E. Foundations	—	LS	—	$60,000	D	$60,000
F. Floor Slabs	5000	SF	$8	$40,000	D	$40,000
G. Sidewalk Slabs	1000	SF	$6	$6,000	D	$6,000

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4.) Estimate prepared March 20, 1992.

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
Interior:						
A. Masonry Block Walls	2200	SF	$4	$8,800	D	$8,800
B. Gypsum Board Walls	1400	SF	$2	$2,800	D	$2,800
C. Suspended Ceiling	700	SF	$5	$3,500	D	$3,500
D. Doors and Frames	210	SF	$18	$3,780	D	$3,780
E. Bathroom Equipment	—	LS	—	$12,000	D	$12,000
F. Laboratory Equipment	—	LS	—	$35,000	D	$35,000
F. Misc. Metal Stairs & pltfrms.	—	LS	—	$9,600	D	$9,600
G. Laboratory Furniture	—	LS	—	$7,000	D	$7,000
H. Misc. Handrails	—	LS	—	$3,600	D	$3,600
I. Painting	—	LS	—	$12,000	D	$12,000
Exterior:						
A. Overhead Doors	240	SF	$48	$11,520	D	$11,520
B. Man Doors	210	SF	$18	$3,780	D	$3,780
C. Windows	192	SF	$24	$4,608	D	$4,608
D. Exterior Stairs	96	R	$66	$6,336	D	$6,336
E. Calkwalk System	1000	SF	$10	$10,000	D	$10,000
4. Tank Foundations and Misc. Structural	—	LS	—	$50,000	D	$50,000
5. Process System						
A. G.W. Equalization Tank	—	LS	—	$116,640	D	$116,640
B. L.G.C. Equalization Tank	—	LS	—	$17,500	D	$17,500
C. Inclined Plate Settler	—	LS	—	$110,000	D	$110,000
D. SBR Tank & Equipment	—	LS	—	$650,000	D	$650,000
E. Sand Filters	—	LS	—	$49,800	D	$49,800
F. Filtrate Holding Tank	—	LS	—	$8,500	D	$8,500
G. Carbon Adsorbtion System	—	LS	—	$450,000	D	$450,000
H. Carbon Backwash Tank	—	LS	—	$25,700	D	$25,700
I. Effluent Monitoring Tank	—	LS	—	$4,300	D	$4,300
J. Filter Press	—	LS	—	$525,000	D	$525,000
K. NaOH Tank	—	LS	—	$11,400	D	$11,400
L. Ferric Tank	—	LS	—	$5,800	D	$5,800
M. PAC Tank	—	LS	—	$5,700	D	$5,700
N. Air Compressor	—	LS	—	$18,300	D	$18,300
O. Metering Pumps (P-114,115, & 116)	—	LS	—	$4,600	D	$4,600
P. Pumps (P-102,111,112, & 119)	—	LS	—	$27,600	D	$27,600
Q. G. W. Feed Pumps	—	LS	—	$22,600	D	$22,600
R. L.G.C. Feed Pumps	—	LS	—	$21,900	D	$21,900
S. Thickened Sludge Pumps	—	LS	—	$3,100	D	$3,100
T. SBR Sludge Discharge	—	LS	—	$20,700	D	$20,700
U. Filter Feed Pumps	—	LS	—	$20,300	D	$20,300

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COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
V. Carbon Units Feed Pumps	—	LS	—	$22,575	D	$22,575
W. Carbon Backwash Pumps	—	LS	—	$27,650	D	$27,650
X. Composite Sampler	—	LS	—	$3,460	D	$3,460
Y. Submersible Aerator	—	LS	—	$24,840	D	$24,840
Z. Submersible Mixer	—	LS	—	$9,720	D	$9,720
AA. Skimmer	—	LS	—	$2,375	D	$2,375
BB. Debagger	—	LS	—	$10,152	D	$10,152
CC. Polymer Feed Systems	—	LS	—	$15,550	D	$15,550
DD. Hydropnuematic System	—	LS	—	$8,640	D	$8,640
EE. Misc Equipment	—	LS	—	$75,000	D	$75,000
6. Process Piping & Valves	—	LS	—	$150,000	D	$150,000
7. Electrical						
A. Incoming Services	—	LS	—	$20,000	D	$20,000
B. Motor Control Center	1	EA	$150,000	$150,000	D	$150,000
C. Power Distribution	—	LS	—	$140,000	D	$140,000
D. Heat Trace	—	LS	—	$18,000	D	$18,000
E. Lighting	—	LS	—	$90,000	D	$90,000
G. Security System	—	LS	—	$30,000	D	$30,000
Control Panel	1	EA	$150,000	$150,000	D	$150,000
Field Instrumentation	—	LS	—	$20,000	D	$20,000
8. Fire Suppression	—	LS	—	$24,000	D	$24,000
9. Exhauster	2	EA	$8,400	$16,800	D	$16,800
10. Heating & Vent.						
A. Misc. Blowers	3	EA	$1,400	$4,200	D	$4,200
B. Ductwork, Air Handler, & Gas Htr.	—	LS	—	$75,000	D	$75,000
11. Temperature Controls	—	LS	—	$14,400	D	$14,400
12. Plumbing	—	LS	—	$50,000	D	$50,000
13. Septic System	—	LS	—	$32,200	D	$32,200
		Item 44 Total :		$4,017,728		

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COMBE FILL SOUTH LANDFILL
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MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
15. Effectiveness Monitoring Wells						
A. 2–inch diameter PVC Monitor Wells (Base depth of 40 feet)	18	EA	$3,600	$64,800	C	$87,480
B. 4–inch diameter PVC Monitor Wells (Base depth of 35 feet)	11	EA	$3,250	$35,750	C	$48,263
C. 6–inch diameter PVC Monitor Wells (Base depth of 70 feet)	9	EA	$9,090	$81,810	C	$110,444
D. 6–inch diameter steel bedrock monitor wells (Base depth of 75 feet)	6	EA	$7,865	$47,190	C	$63,707
E. 6–inch diameter steel off–site bedrock monitor wells (Base depth of 100 feet)	3	EA	$14,300	$42,900	D	$42,900
F. 6–inch diameter steel off–site bedrock monitor wells (Base depth of 150 feet)	3	EA	$19,565	$58,695	D	$58,695
[illegible]inch diameter steel off–site bedrock [illegible]itor wells (Base depth of 200 feet)	3	EA	$25,315	$75,945	D	$75,945
16. Add or Deduct per VLF of Effectiveness Monitoring System						
A. 2–inch diameter PVC monitor wells	150	VLF	$90	$13,500	C	$18,225
B. 4–inch diameter PVC monitor wells	100	VLF	$95	$9,500	C	$12,825
C. 6–inch diameter PVC monitor wells	150	VLF	$130	$19,500	C	$26,325
D. 6–inch diameter steel bedrock monitor wells	100	VLF	$105	$10,500	C	$14,175
E. 6–inch diameter steel off–site bedrock monitor wells	250	VLF	$105	$26,250	D	$26,250

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COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
47. Grouting Existing Monitoring Wells and Borehole Abandonment						
A. Grouting Existing Monitoring Wells	1,500	VLF	$14	$21,000	D	$21,000
B. Borehole Abandonment	500	VLF	$14	$7,000	D	$7,000
48. Erosion and Sediment Control	70	AC	$4,500	$315,000	D	$315,000
49. Chain Link Fence						
A. Chain Link Fence Installation						
1. Fencing	8900	LF	$18	$160,200	D	$160,200
2. Corner Posts	15	EA	$115	$1,725	D	$1,725
3. Bracing	30	EA	$42	$1,260	D	$1,260
4. Gates	—	LS	—	$14,000	D	$14,000
B. Chain Link Fence Grounding	40	EA	$50	$2,000	D	$2,000
50. Decontamination Area and Facilities						
1. Concrete Pad	800	SF	$13	$10,400	D	$10,400
2. Sump	1	EA	$1,600	$1,600	C	$2,160
3. Holding Tank (assume 1000 gal steel UST)	1	EA	$5,000	$5,000	C	$6,750
4. Personell Decontamination Trailer	1	EA	$45,000	$45,000	D	$45,000
51. Air Monitoring Plan						
A. Air Monitoring Plan	—	LS	—	$20,000	D	$20,000
B. Additional Testing of Sorbent Tubes	100	EA	$150	$15,000	D	$15,000
52. Dust Migration Control Plan						
1. Develop Plan	—	LS	—	$20,000	D	$20,000
2. Implement Plan	18	MO	$3,000	$54,000	D	$54,000

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COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
3. Environmental Pollution Control Plan Development	—	LS	—	$10,000	D	$10,000
4. Spill and Discharge Control Plan						
1. Develop Plan	—	LS	—	$20,000	D	$20,000
2. Implement Plan	—	LS	—	$10,000	D	$10,000
5. Quality Control Plan Development						
1. Develop Plan	—	LS	—	$20,000	D	$20,000
2. Implement Plan	36	MO	$4,000	$144,000	D	$144,000
6. Security Plan						
1. Develop Plan	—	LS	—	$5,000	D	$5,000
2. Implement Plan						
[illegible]rsonell–Full time until site fenced	6	MO	$11,500	$69,000	D	$69,000
[illegible]rsonell–12 hrs per day after fence	30	MO	$5,700	$171,000	D	$171,000
c. Building and Site Communication	—	LS	—	$5,000	D	$5,000
7. Health and Safety Plan						
1. Develop Plan	—	LS	—	$30,000	D	$30,000
2. Implement Plan	36	MO	$4,000	$144,000	D	$144,000
8. Drum Removal	100	EA	$1,000	$100,000	D	$100,000
9. Test Pit Excavation and Backfilling	25	EA	$550	$13,750	C	$18,563
0. Erosion Control Matting	11,000	SY	$5	$55,000	D	$55,000

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SUPERFUND SITE
MORRIS COUNTY, NEW JERSEY

CONSTRUCTION COST ESTIMATE

ITEM	QUANTITY	UNITS	UNIT COST	COST	ASSUMED LEVEL OF WORK	TOTAL COST
Operation and Maintenance – First Year						
A. Labor	—	LS	—	$250,000	D	$250,000
B. Chemicals	—	LS	—	$664,500	D	$664,500
C. Sludge Disposal	—	LS	—	$3,600	D	$3,600
D. Utilities	—	LS	—	$229,600	D	$229,600
E. Sampling & Analysis (for process control)	—	LS	—	$30,000	D	$30,000
		Item 61 Total :		$1,177,700		
Operation and Maintenance – Second Year						
A. Labor	—	LS	—	$250,000	D	$250,000
B. Chemicals	—	LS	—	$498,400	D	$498,400
C. Sludge Disposal	—	LS	—	$2,700	D	$2,700
D. Utilities	—	LS	—	$229,600	D	$229,600
E. Sampling & Analysis (for process control)	—	LS	—	$30,000	D	$30,000
		Item 62 Total :		$1,010,700		
			Without Item #1 & #2		Sub–total	$47,996,948
			With Item #1 & #2		Total :	$49,676,842

Note: 1.) Items involving work requiring level C protection assume additional 35% mark–up for productivity losses.
2.) Items involving work requiring level D+ protection assume additional 13% mark–up for productivity losses.
3.) Items involving work requiring level D protection assume no additional mark–up for productivity losses.
Estimate prepared March 20, 1992.

SECTION 12 - GROUND WATER RECOVERY SYSTEM EFFECTIVENESS MONITORING PLAN

The primary objective of the ground water recovery system effectiveness monitoring program is to determine if the ground water recovery system is preventing contaminated ground water in the overburden from flowing off site. The monitoring of ground water quality will provide the primary documentation of the effectiveness of the shallow ground water recovery system. This quality approach has been selected instead of the use of ground water elevation data for two reasons: 1) acceptable ground water quality off-site is the ultimate goal of the site remediation; and 2) the mapping of the ground water table to a sufficient degree of accuracy to document ground water contamination would require an excessively large number of wells both on and off the landfill. In order to meet the objective, OB&G initially proposed that a series of monitoring wells be installed outside the recovery well system to monitor the quality of water downgradient of the recovery wells. Ground water from the monitoring wells will be sampled on a quarterly basis to determine if contaminated shallow ground water is being collected by the ground water recovery system. Ground water levels will be measured monthly in these wells and the existing wells for at least one year from the date the recovery well system begins operation. This will assist in evaluating the effectiveness of the shallow ground water recovery system.

In addition, at the request of the NJDEP, piezometers will be installed around several of the recovery wells to examine head at varying locations from these wells. Eight piezometers will also be installed on the landfill face. The evaluation of head data will be another means of determining the system's effectiveness.

The monitoring well system will consist of twelve wells, one upgradient (MW-11) and eleven at downgradient locations (Figure 12-1). Eight on-site piezometers (PZ-1 to PZ-8) will also be installed to evaluate the impact of the recovery system on the ground water elevations within the landfill. In addition, piezometers will be installed around four of the recovery wells to more clearly define drawdown around these wells (PZ-9 to PZ-28). Five piezometers will be installed at each of these recovery wells, at upgradient and downgradient locations as well as between adjacent recovery wells. Figure 12-1 shows placement of those piezometers around recovery wells B, F, I and P. These piezometers will be used to evaluate changes in water levels around the recovery wells to further evaluate the effectiveness of the ground water recovery system.

Monitoring wells will be constructed of 4-inch I.D. PVC screen and riser. Piezometers will be constructed of 2-inch I.D. PVC screen and riser. Piezometers on the landfill face, however, will be constructed of 6-inch I.D. PVC screen and riser. Six-inch piezometers on the landfill face were requested by the NJDEP so that they could be pumped should the ground water recovery system fail or a need arise to reduce ground water levels within the landfill. Monitoring wells and piezometers will be drilled 4 feet into bedrock where drilling equipment allows. Bedrock boreholes will be sealed with a cement/bentonite grout prior to piezometer installation.

Material used for the filter pack should meet these specifications for the commercially available Morie #00 or an equivalent filter pack:

WELL/PIEZOMETER	DIAMETER	MATERIAL	APPROX. WELL DEPTH (FT.)
MW-1	4"	PVC	30
MW-2	4"	PVC	20
MW-3	4"	PVC	25
MW-4	4"	PVC	30
MW-5	4"	PVC	45
MW-6	4"	PVC	45
MW-7	4"	PVC	20
MW-8	4"	PVC	10
MW-9	4"	PVC	55
MW-10	4"	PVC	55
MW-11	4"	PVC	55
MW-12	6"	STEEL	90
MW-13	6"	STEEL	85
MW-14	6"	STEEL	85
MW-15	6"	STEEL	65
MW-16	6"	STEEL	65
MW-17	6"	STEEL	65
PZ-1	6"	PVC	65
PZ-2	6"	PVC	95
PZ-3	6"	PVC	95
PZ-4	6"	PVC	90
PZ-5	6"	PVC	75
PZ-6	6"	PVC	60
PZ-7	6"	PVC	45
PZ-8	6"	PVC	70
PZ-9	2"	PVC	35
PZ-10	2"	PVC	30
PZ-11	2"	PVC	25
PZ-12	2"	PVC	30
PZ-13	2"	PVC	60
PZ-14	2"	PVC	55
PZ-15	2"	PVC	60
PZ-16	2"	PVC	60
PZ-17	2"	PVC	40
PZ-18	2"	PVC	40
PZ-19	2"	PVC	30
PZ-20	2"	PVC	20
PZ-21	2"	PVC	65
PZ-22	2"	PVC	55
PZ-23	2"	PVC	55
PZ-24	2"	PVC	55
PZ-25	2"	PVC	55
PZ-26	2"	PVC	55
PZ-27	6"	PVC	90

LEGEND

- 760 EXISTING GRADE
- x—x—x EXISTING FENCE
- PROPERTY LINE
- (A) RECOVERY WELL LOCATION
- PROPOSED 4-INCH MONITOR WELL
- PROPOSED 2-INCH OR 6-INCH MONITOR WELL
- PROPOSED BEDROCK MONITOR WELL
- EXISTING GROUND WATER MONITORING WELL
- PTO-2 BORING; GAS TEST WELLS

In charge of	Designed by	Checked by	Made by

200 0 200 400
1"=200'

NO.	DATE	REVISIONS	INIT.

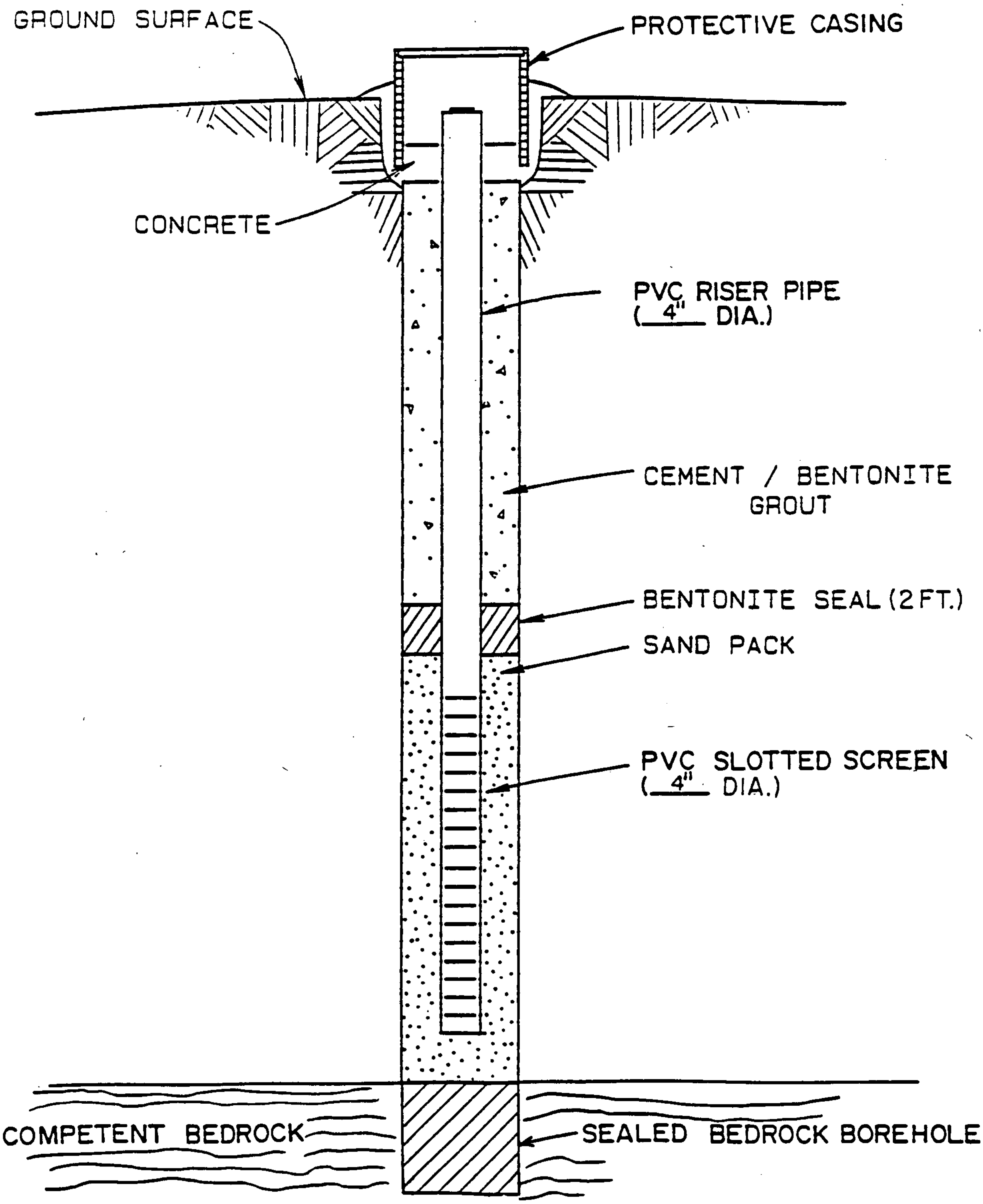
O'BRIEN & GERE ENGINEERS, INC.
Syracuse, New York

COMBE FILL SOUTH LANDFILL
SUPERFUND SITE
NEW JERSEY DEPARTMENT OF
ENVIRONMENTAL PROTECTION

GEOLOGIC
COMBE FILL SOUTH
EFFECTIVENESS MONITORING SYSTEM

FILE NO. 3013.012-42F
DATE FEBRUARY 1992
FIG 12-1

COMBELF1 .1 .3 .6 .10 .26 .28,29,30 .39,40 .46,47 .52
3013.012.40



TYPICAL MONITORING WELL

NOT TO SCALE

063397

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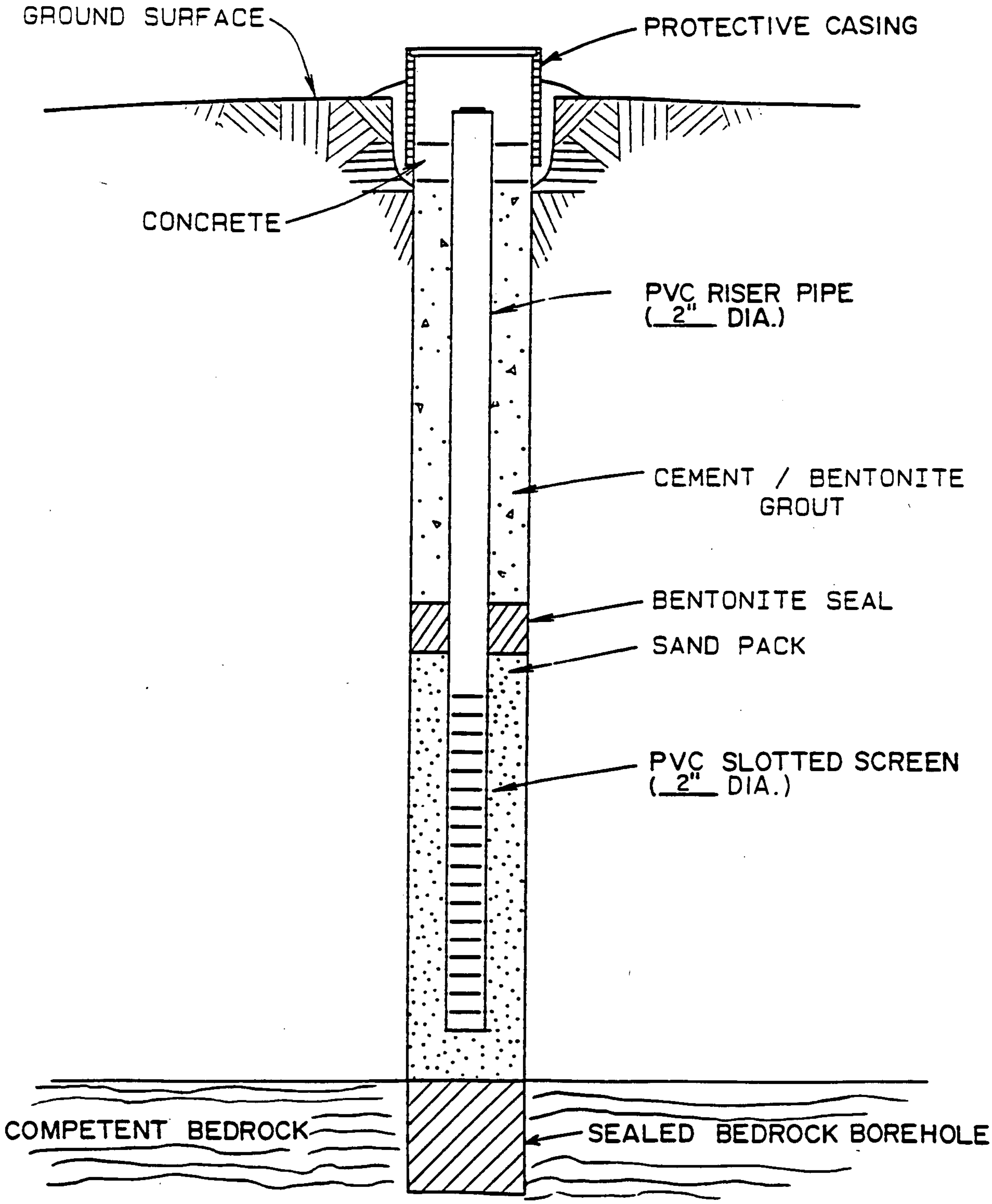
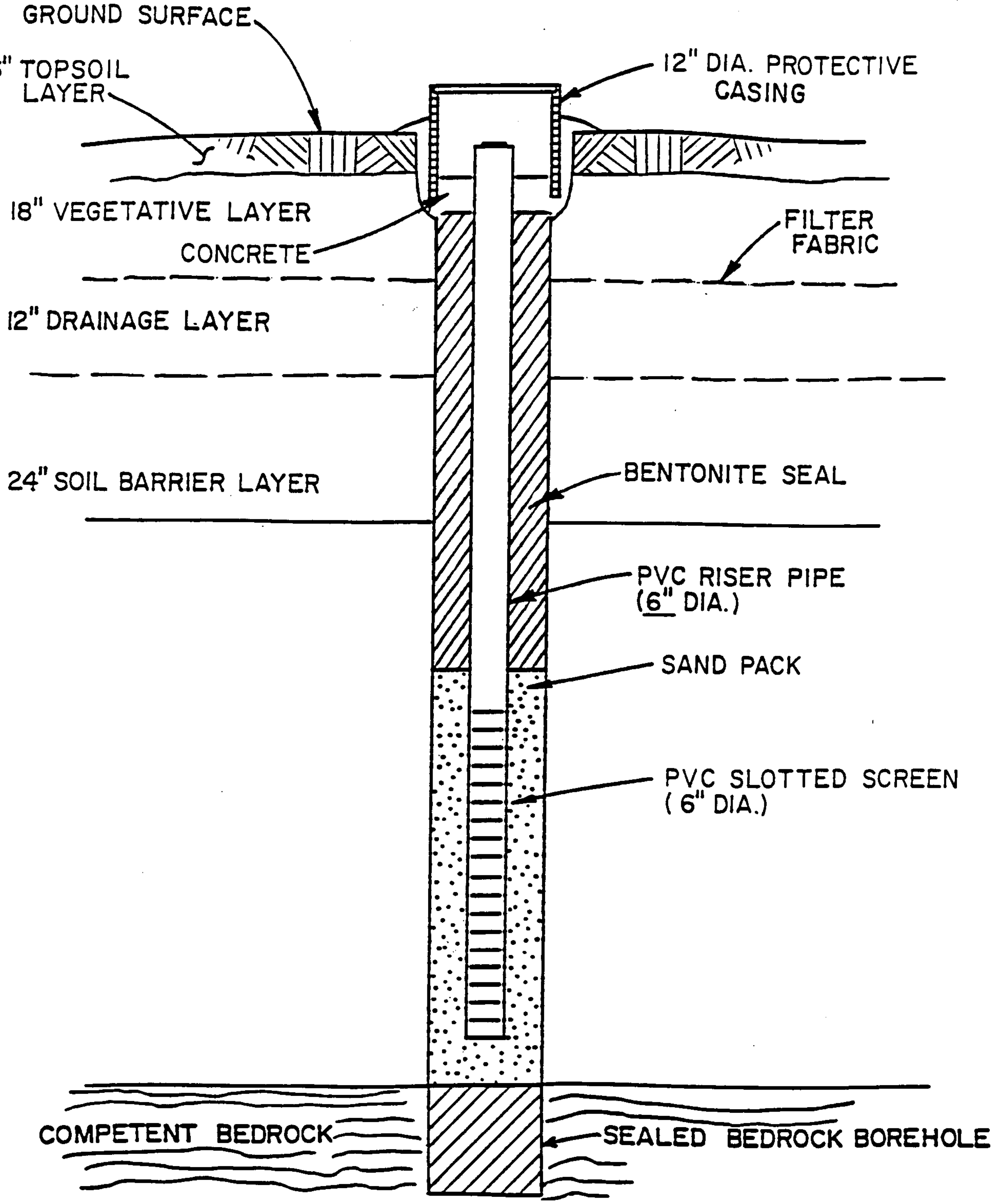


TYPICAL PIEZOMETER

NOT TO SCALE

063397

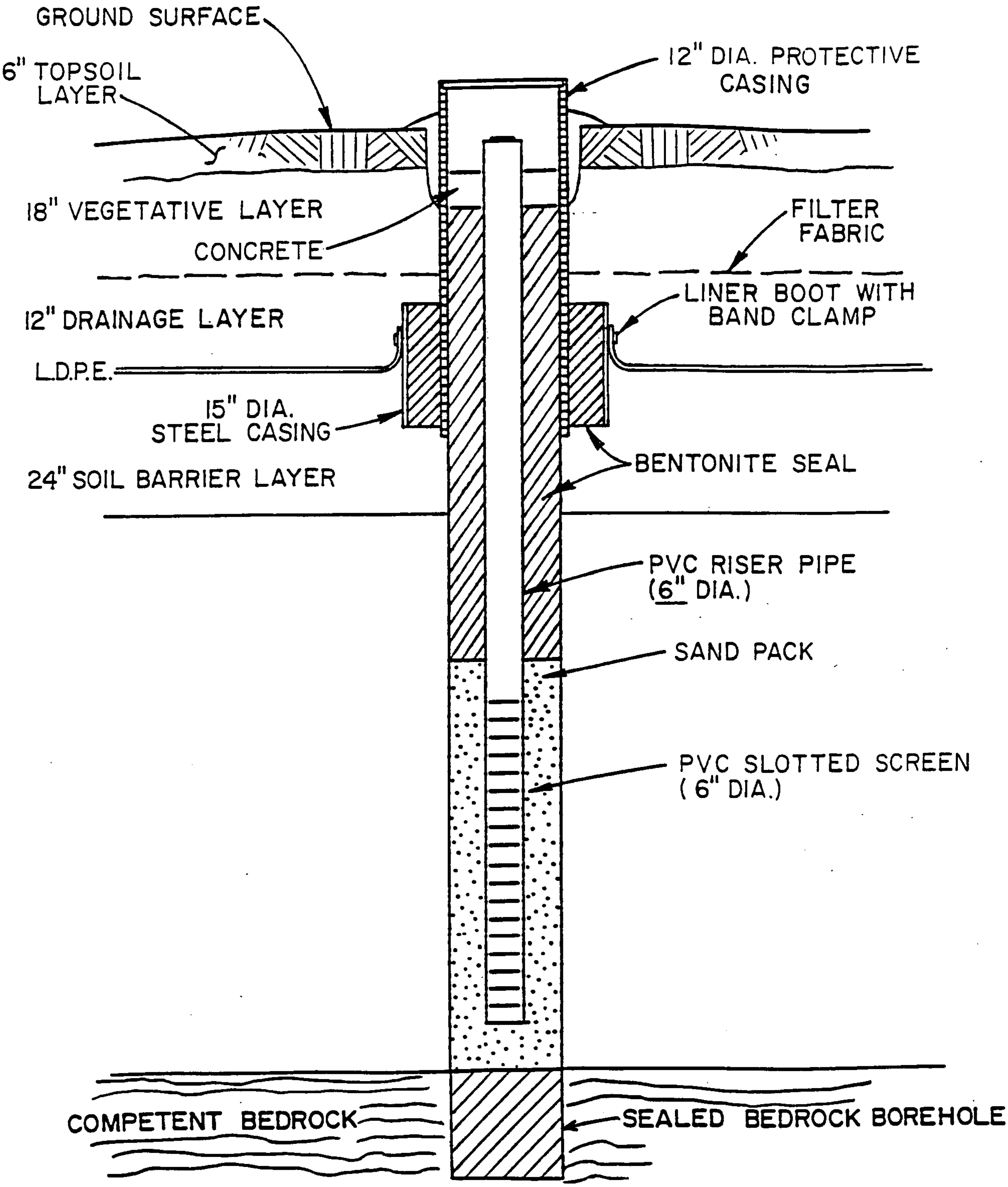
O'BRIEN & GERE ENGINEERS, INC.



TYPICAL PIEZOMETER ON THE LANDFILL FACE

NOT TO SCALE

063397



TYPICAL PIEZOMETER THROUGH L.D.P.E. LAYER

NOT TO SCALE

063397

O'BRIEN & GERE ENGINEERS, INC.

TABLE 12-1

EXISTING WELLS AT COMBE FILL SOUTH

Well Number	Proposed Stations	Reason
S-6	Preserved	Upgradient monitoring location
S-1	Abandoned	Too close to recovery well system to monitor downgradient water quality
S-1	Abandoned	Interior well - will most likely be destroyed when landfill is capped
S-3	Abandoned	Too close to recovery well system to monitor downgradient water quality
S-4	Abandoned	Interior well - will most likely be destroyed when landfill is capped
S-5	Abandoned	Abandonment requested by NJDEP
S-8	Abandoned	Abandonment requested by NJDEP
SB-1	Abandoned	Too close to recovery well system to monitor downgradient water quality
SB-2	Abandoned	Too close to recovery well system to monitor downgradient water quality
SB-3	Abandoned	Interior well - will most likely be destroyed when landfill is capped
SB-4	Abandoned	Too close to recovery well system to monitor downgradient water quality
SW-2	Abandoned	Requested by NJDEPE
SW-4	Abandoned	Too close to recovery well system to monitor downgradient water quality
S-7	Preserved	Requested by NJDEPE
PT-1	Abandoned	Requested by NJDEPE
PT-01	Abandoned	Requested by NJDEPE
PT-2	Abandoned	Requested by NJDEPE
PT-04	Abandoned	Requested by NJDEPE
PT-3	Abandoned	Requested by NJDEPE
PT-05	Abandoned	Requested by NJDEPE

TABLE 12-1

EXISTING WELLS AT COMBE FILL SOUTH
(Continued)

Well Number	Proposed Stations	Reason
PT-06	Abandoned	Requested by NJDEPE
PT-07	Abandoned	Requested by NJDEPE
PT-08	Abandoned	Requested by NJDEPE
PT-02	Preserved	Requested by NJDEPE
PT-4	Preserved	Requested by NJDEPE
PT-03	Preserved	Requested by NJDEPE
S-7	Preserved	Requested by NJDEPE

*Note:

Well D-1 through D-9, as well as DW-2 and DW-4, are bedrock monitoring wells and thus are not proposed for use in monitoring shallow ground water quality. However, these wells will be preserved where possible for future monitoring of bedrock water quality.

Gram Size	Percent Retained
0.3 mm	100%
0.6 mm	50%
0.65 mm	30%
0.75 mm	10%

A 0.010 inch screen slot size is proposed. Figure 12-2 and 12-3 are schematics for typical monitoring wells and piezometers, respectively. Figures 12-4 and 12-5 are schematics for typical piezometers on the landfill face and typical piezometers through the LDPE layer, respectively.

Locations of the existing wells at the site were analyzed to determine if they could be incorporated into the monitoring plan. Well S-6, an existing upgradient well at the north end of the site, will be used as the upgradient monitoring well (MW-11) for this plan. The proposed downgradient wells have been placed radially around the site perimeter to monitor ground water quality at all downgradient locations. A list of existing wells and their status in relation to possible use as monitoring wells is presented in Table 12-1. The other perimeter wells are located too close to the recovery well system to be used for quality monitoring. The flow paths of ground water from the site to each of the recovery wells are estimated to extend downgradient approximately 100 ft before water is drawn into the recovery well. Thus monitoring wells should be located at least 100 ft downgradient so as not to be within the recovery well flow paths. The proposed recovery wells are located at the edge of the proposed cap and access road, and most existing perimeter monitoring wells are very close to this proposed cap perimeter. These wells are too close to the recovery well system to effectively monitor the downgradient ground water quality.

They will most likely be destroyed in construction of the proposed access road. However, these wells will be preserved where possible, and will be used to monitor water levels at the site.

In order for the ground water flow paths determined from the calculations to be developed, a certain amount of time is required. This is due to the low ground water flow velocities. Prior to attaining equilibrium, partial cone development would allow contaminants to migrate past the recovery wells and be detected in the monitoring wells. The present recovery well system will require approximately 180 to 365 days to reach equilibrium. Once equilibrium is attained, the cones of influence will be stabilized such that ground water discharging from the site is collected by the recovery wells.

Ground water levels will be collected on a monthly basis for at least one year from the start of the recovery well system operation to evaluate the effectiveness of the system. In addition, the monitoring wells will be sampled quarterly to determine if contaminated water is passing the recovery well system and migating off-site. Initially, the wells will be analyzed for Target Compound List/Target Analyte List plus 30 (TCL/TAL+30) compounds. Depending on results of these analyses, TCL/TAL+30 analyses may not be necessary for further sampling occasions. Contaminants previously identified in the shallow saprolite aquifer include volatiles at concentrations ranging from 4.7 parts per billion (ppb) in well S-6 to 1,556 ppb in well S-1. Base/neutrals were detected in wells S-2, S-3 and S-4 at concentrations ranging from 13 ppb in well S-3 to 49 ppb in well S-2. Chromium, copper, lead, nickel and zinc were detected in low concentrations in the shallow wells. In addition, phenols were detected in well S-1 at a concentration of 270 ppb. Quarterly monitoring of the wells will be conducted to monitoring ground water quality such that these previously detected contaminant levels are reduced as contaminated ground water is collected by the recovery well system.

SECTION 13 - PRELIMINARY OPERATIONS AND MAINTENANCE PLAN

13.01 General

Closure of the Combe Fill South Landfill includes the following major components:

- Low Permeability Cover
- Active Gas Extraction System
- Ground Water Collection and Treatment System

In addition to these major components, ancillary facilities include site fencing, main and perimeter access roads, and ground water monitoring wells.

This section outlines inspection and maintenance activities to be conducted during the post-closure period. In accordance with the requirements of 40 CFR Part 264, it is anticipated that the closure period will extend 30 years beyond completion of the construction of the above discussed facilities.

13.02 Physical Site Security

An eight foot high chain-link fence topped with one foot of barbed wire will be installed surrounding the remediated site areas the ground water treatment facility, the building housing the exhausters, and the enclosed flare (thermal oxidizer). Access to the site will be controlled by a locking gate located at the junction of the proposed paved access road and Parker Road. Appropriate warning signs will be located around the perimeter of the site to discourage trespassers. The fence should be inspected routinely for damage from vandals or other causes. If damage is discovered, it should be repaired as soon as possible.

13.03 Access Road

During the routine inspections, the inspector should walk along the main and perimeter access roads and look for rutting, potholes, or settlement. Should any of these conditions be observed, they should be corrected by filling with appropriate material. During the winter months, the road should be plowed after snow falls, and the snow banks arranged to promote offsite drainage when thawing occurs.

13.04 Cover Inspection and Maintenance

A routine inspection of the closed landfill and immediately adjacent areas should be performed monthly for the first year after closure and quarterly thereafter. The inspector should observe and note the condition of the cap and the vegetative cover. Should areas of settlement, erosion, or slope instability be noted, regrading should be conducted to promote drainage and minimize the percolation of water into the landfill.

No shrubs, brush, or deep rooting weeds will be allowed to germinate or grow on the cover. If visual observation indicates that deep rooting vegetation has established on the cover, a weed control program should be implemented. The inspector should also note any problems with insect damage or thinning of vegetation. If insect damage is noted, an extermination program should be implemented. Areas of vegetation which appear to be thinning out over time will require reseeding to keep the vegetative cover as dense and uniform as possible. Mowing will occur once during the spring, once during the summer, and once during the fall.

The cover should also be inspected for the presence of rodents or burrowing animals. If there is any evidence of either of these vectors, an extermination program should be implemented.

During the routine inspections of the cover, safety equipment for the inspector should include, as a minimum, a work uniform, steel toed boots, and a two way portable radio.

13.05 Drainage

Inspection of drainage facilities should be conducted at the same interval as the cover inspection. Drainage ditches should be inspected for accumulation of debris which may inhibit flow and for excessive scouring which may erode the ditch. Should debris accumulation be noted, the ditch should be promptly cleaned to maintain flow capacity. If excessive scouring is noted, rip-rap should be added to the bottom of the ditch. The perimeter of the cover drainage layer and drainage piping should be inspected to insure that it remains free draining. If plugging of the drainage piping is noted, they should be cleaned either by flushing or pigging.

The inspections of drainage facilities should be conducted concurrently with inspection of the cover. During routine inspections of drainage facilities, safety equipment for the inspector should include, as a minimum, a work uniform and steel toed boots.

13.06 Ground Water Monitoring Wells

Ground water monitoring wells should be inspected monthly during the first year following closure and yearly thereafter for signs of tampering. If the wells have been tampered with, they should be promptly repaired. If an area has excessive fine material, plugging may occur. This may be indicated by slow recovery times, cloudy samples, or insufficient sample volume. If plugging due to tampering or natural siltation becomes a problem, the well should be redeveloped by bailing, air purging or other appropriate methods. If plugging continues to be a problem following re-development, it may become necessary to replace the damaged well or wells or modify sampling procedures.

No smoking or open flame should be allowed when inspecting the monitoring wells. Minimum safety requirements for the inspector should consist of a work uniform and steel toed boots.

13.07 Gas Extraction System

The active gas extraction system is to consist of a total of 66 individual wells each connected to one of five headers. Each header services from 13-14 extraction wells in one of the five sections of the landfill, with the headers being manifolded to exhausters located in the exhauster building. Treatment of the extracted gas will be provided by flaring via an enclosed flare.

The active gas extraction system is designed to control gas seepage from the landfill. The wells are placed within the landfill to draw the generated landfill gas to the wells. The exhausters are designed to create a vacuum on the wells; and the landfill gas is collected for treatment, in this case, flaring by an enclosed flare.

13.07.01 Wells

Description

A total of 66 extraction wells will be installed to capture the gas being generated at the landfill. Thirty-seven perimeter wells will be installed on 200 foot centers no closer than 50 feet to the edge of the refuse. Each perimeter well will be installed to the top of the ground water table, thus, providing a seal against offsite migration of landfill gas. On the interior of the landfill, twenty-nine wells will be installed. Each of these wells will be installed to two-thirds the total depth of refuse or to the top of the ground water table, whichever is more shallow.

Purpose

The extraction wells will be installed to provide a means of collecting generated landfill gas.

Special Features

The lower and upper portion of the well screen will be 4 inch diameter schedule 40 PVC pipe and the middle portion of the pipe will be 6 inch diameter schedule 40 PVC. The well casing will be 4 inch diameter schedule 40 PVC. The 4 inch and 6 inch diameter portions of the well screen will be connected utilizing telescoping joints which will be capable of accommodating more than four feet of landfill settlement.

Connected to each well will be a 3 inch butterfly valve with a 1/4 inch plug fitting on each side of the valve for measuring negative pressure at the well head. These are designed for balancing the extraction rate of the wells and also providing a means of isolating repairs and/or maintenance. The extraction wells will be connected to either below ground or above ground header pipe, depending on their location in the landfill. The wells extending above ground will be insulated above ground to reduce the amount of condensate being formed in the header. Both the above grade and the below grade connected wells are able to be serviced from the surface by the four inch threaded PVC cap.

Operating Procedures

Under normal operating conditions, landfill gas is extracted from the wells by a balanced negative pressure system exerted on the well heads by the exhausters. First, the gas is extracted from the wells into one of five headers, then the gas is drawn into one of the exhausters located in the exhaust building, where it is ultimately sent to the enclosed flare.

Maintenance

Inspection of the extraction wells should be conducted at the same interval as the cover inspection or as otherwise dictated by system operational needs. Extraction wells should be inspected for balance of the extraction system, accumulation of debris, signs of vandalism, signs of settlement, and other items that may inhibit the optimum extraction rate. If accumulation of debris is noted, the wells should be promptly cleaned. The butterfly valves will have a removable or locking actuator handle to prevent unauthorized use of the valve which could disturb the balance of the extraction system. The extraction system should be balanced routinely to maintain the optimum extraction rate for the system. This will be accomplished by measuring the pressure at the furthest well and all the other wells along the system and adjusting the valves along the line accordingly. Complete balancing of the system will require several iterations of this process.

13.07.02 Gas Extraction Piping

Description

Both above and below grade piping is used in the gas extraction piping system to transport the landfill gas to the gas treatment facility. Below ground piping will be utilized in areas of the landfill with capped slopes greater than 10%. At slopes of less than 10% fiberglass piping will be installed above ground. The above ground piping will be insulated in order to minimize condensate production, prevent condensate from freezing and minimize expansion and contraction of the piping. The above ground fiberglass pipes will require pipe supports, with support spacing depending on the pipe diameter. Valve boxes will be installed at major branches in the header system to aid in balancing sections of the header, as well as, providing a means of shutting down sections of the header for repairs.

Purpose

The gas extraction header piping is designed to transport the extracted landfill gas from the well heads to the exhausters located in the exhauster building.

Special Features

The gas extraction piping includes features to accommodate landfill settlement, minimize friction losses, facilitate operation and maintenance, minimize vandalism, and collect condensate.

The below ground piping is installed in the drainage layer, whereas, the above ground pipes are supported on adjustable pipe supports. The pipes have protection saddles to protect insulation resting on the pipe supports from damage. The adjustable cross member is utilized to raise or lower the pipe to accommodate landfill settlement so that drainage of condensate is maintained. Piping is kept at a minimum 18 inches above grade to allow for mowing.

The gas collection system header pipe varies from four inches to eight inches in diameter in two inch increments. Smaller diameter pipe is used at the end of the header furthest from the exhauster, and increases as more wells discharge to the header. The size of the header is designed to minimize the head losses associated with pipe friction. The pipes are designed so that there will be less than eight inches of water column lost between the two most widely separated wells on a given header. This minimal friction loss is designed to balance the system so that the two most widely separated wells on a given header will have the same vacuum.

The extraction piping incorporates valves to aid in balancing the system. Gas extraction piping is designed so that condensate withdrawn from the landfill will flow by gravity to condensate pump stations from where it will be pumped to the on-site treatment facility.

Operating Procedures

Under normal operating conditions, the gas extraction piping is designed to transport the generated landfill gas from the well heads to the exhauster building, and then to the direct flame flare using a balanced negative pressure system. To maintain this optimum extraction rate the system needs to be routinely balanced. To complete a balance on the system, the pressure must be measured at each well starting with the furthest well and subsequently each well along the system. The pressure must be adjusted accordingly to balance the system so that the two most widely separated wells on a given header will have the same vacuum.

Maintenance

Gas collection headers can be subject to several potential maintenance problems, such as, pipe breakage due to thermal contraction or expansion, pipe movements due to landfill settlement, condensate blockage problems, and vandalism. In anticipation of these potential problems, a routine program inspection and maintenance should be established. Tools and pipe materials should be readily available for routine repair of the line, and pipe slopes should be checked and adjusted as required. Also, the gas extraction piping should be routinely balanced to maintain the optimum extraction rate, this can be accomplished by taking pressure measurements at the various wells and adjusting the valves accordingly. The valve boxes will provide access to facilitate cleaning when the header system requires cleaning. The condensate collection piping should be routinely checked for clogs especially in the "J" tubes. Prior to entering the condensate collection manhole to inspect the condensate tubes, the air must be monitored by an oxygen meter and an explosimeter to determine if there are any hazards present. The air monitoring regulations outlined in 29 CFR 1926.800 must be followed during air monitoring of the manholes.

13.07.03 Exhausters

Description

The gas extraction system consists of three operating exhausters and a fourth spare exhauster. The site geometry and the number of installed gas extraction wells along with input from NJDEP influenced the design of the system. Each exhauster will service from 11 to 14 wells.

Purpose

The exhausters are designed to provide suitable vacuum at each well to draw the extracted landfill gas through the pipes to the exhaust building and eventually to the direct flame flare.

Special Features

Each exhauster is sized to handle from 330 to 700 CFM of landfill gas (11 to 14 wells each being pumped at rates varying from 30 to 50 CFM). Excess pumping capacity is available. Each exhauster is powered by a 230/460 volt, 15 horsepower explosion proof electric motor. The exhauster impeller and other operating parts are coated with a phenolic coating to prevent corrosion.

The piping on both the inlet and the outlet side of the exhausters are manifolded to allow for the following; ease in utilization of the spare exhauster, operation of multiple headers on a single exhauster, and to permit flexibility in discharge to the direct flame flare. Butterfly valves are used for throttling and isolating sections of the piping. Fittings are included to allow monitoring of gas volume, pressure and gas composition.

Operating Procedures

The flow rate of the exhausters must be adjusted by means of throttling the butterfly valves to obtain the optimum extraction rate for the system. Once the gas extraction system is in place, actual rates of gas production will be ascertained and the exhausters can be adjusted accordingly. In the event that gas production drastically decreases, it is possible to combine two or more headers on a single exhauster.

Maintenance

The exhausters should be routinely inspected when the piping inspections are conducted. The exhausters must be adjusted using the butterfly valves when the system is balanced. Maintenance repairs in the headers will effect the operation of the exhausters for that area, therefore, the exhausters will have to be readjusted to accommodate the loss of extraction capacity. During the inspections, the conditions of the various exhausters must be noted and if an exhauster is temporarily out for repair the spare exhauster should be used.

13.07.04 Condensate Collection

Description

The extraction system is designed so that condensate may be collected and discharged to the ground water treatment system to be located on site. The lateral piping from the extraction wells to the headers are sloped toward the header so that condensate will not drain to the well. The laterals empty into the top of the extraction headers and all the headers are sloped toward a condensate collection manhole or vault from which the condensate will be drained by gravity. At the lowest point of the extraction header, at the center of the condensate collection manhole or vault, a "J" tube will drain the condensate from the header pipe. Condensate drains from the collection manhole or vault via gravity to one of two pump stations. Condensate collected in the pump stations is pumped through a valve box to a force main which will discharge to the ground water treatment system.

Purpose

The condensate collection system is designed to collect the condensate generated from the landfill and transport it to the ground water treatment system.

Special Features

The "J" tube designed to automatically drain the condensate from the extraction header is a one inch diameter PVC pipe and its twenty inch minimum length is designed to prevent outside air from being drawn into the gas extraction system. The "J" tube is equipped with a one inch ball valve and a union to facilitate cleaning if it becomes plugged. To facilitate cleaning of the condensate drain line, access manholes are to be placed along the condensate drain line to minimize the length of line to 400 feet or less.

The two condensate pump stations each has a submersible, centrifugal pump mounted on guide rails for easy removal. The pumps are turned on and off by float switches. An alternate switch is used to alternate each pumping cycle. An alarm system is incorporated to signal high and low water levels. The second pump station is sized to handle up to 5,000 gallons per day. The condensate collected in the pump stations is pumped through a valve box to a three inch diameter HDPE force main which discharges to the ground water treatment system.

Operating Procedures

The condensate drain lines are designed to drain by gravity so there is minimal operating procedures here other than routinely checking for clogs. The pumps are designed to operate by means of float switches and an alternate switch, therefore, these switches should be checked to see if they are operating correctly. If the alarm system sounds, the water level should be checked and the pumps should be adjusted accordingly.

Maintenance

The condensate collection system should be inspected routinely for items, such as, breaks in the lines, clogs, and corrosion. Breaks in the pipes should be immediately repaired. If clogs are encountered, the condensate drain lines should be cleaned. Prior to entering the condensate collection manhole, the air must be monitored by both an explosive meter and an oxygen meter to verify the space is safe for entry. The requirements outlined in 29 CFR 1926.800 must be followed during air monitoring. Only when the space is safe should it be entered. It is likely that entry of condensate manholes will require level C protection.

13.07.05 Gas Extraction Building

Description

The gas extraction building is located on site to house the following items; the gas extraction exhausters along with electrical controls, sediment traps, condensate drip traps, ancillary piping, valves and fittings.

Purpose

The gas extraction building is designed to house the systems controls, traps, and other items to centrally locate the controls and to place them in a secure and weather-proof environment.

Special Features

The exhauster building is a pre-engineered metal structure designed with blow off panels in case of explosion. The gas extraction system will contain a ventilation system, a gas detection and alarm system, and a fire suppression system. All the electrical controls for the exhausters are housed in a separate room. The control panel for the enclosed flare (thermal oxidizer) is mounted outdoors along side the unit.

Buried gas extraction header pipes are to be brought above ground entering the gas extraction building to prevent gas migrating along the pipe-line and entering the building at the point of entry of the gas headers.

Condensate collection and transmission to a condensate collection manhole is accomplished by two methods inside the exhauster building. A manual sediment/condensate trap is located on the inlet side of the exhauster designed to remove the majority of the condensate by gravity discharging to a condensate drain. The condensate drains are manifolded together and condensate will flow by gravity through a four inch PVC pipe to the condensate collection manhole. The PVC pipe will discharge to a "J" trap designed to prevent atmospheric air from being drawn into the extraction system. In addition, drip traps located on the discharge side of the exhausters are designed to collect the condensate and discharge to the four inch PVC condensate drain described above.

Operating Procedures

The operating procedures for the various system controls housed in the gas extraction building have been previously discussed in the above sections.

Maintenance

The gas extraction building should be routinely checked to maintain the various controls and items housed in the building. The systems controls and traps located in the exhauster building should be routinely inspected at the same frequency as the piping system and exhausters to verify proper operating procedures and to check for clogs in the condensate drain lines. The drain lines should be cleaned immediately if plugs in the line are noted. The fire suppression should be routinely tested to insure it remains activated.

13.08 Gas Treatment System

Description

An enclosed flare configured as a thermal oxidizer will be used to destroy the collected landfill gas. A mixture of gas and combustion air is thermally oxidized at a minimum temperature of 1500° F. The temperature control is provided with a combustion air control valve. The burner is an inline burner. Auxiliary fuel, in this case natural gas, is used to fuel a pilot flame. The pilot used is a full time process spark ignited pilot and is used for start up. The operation of the pilot is monitored by a UV scanner. A sight port is provided for visual flame inspection. The system is designed to destroy the organics with minimum efficiency of 95%.

The combustion chamber is lined with a ceramic blanket which is coated with a rigidizer for extended service and life. The ceramic blanket insulates the shell from the combustion process and maintains a low skin temperature on the steel shell. The ceramic blanket also provides protection against thermal shock and further reduces the noise level by acting as a noise absorbent. The waste gas inlet is furnished with a grid type of flame arrestor to protect the system against flashback. The flue gas is exhausted from a 35 ft. ceramic blanket lined stack.

Purpose

The gas treatment system is designed to oxidize the extracted landfill gas.

Special Features

The system includes all necessary instrumentation and controls for safe operation of the system. The system is designed for unattended operation. Various interlocks are included in the system, such as, flame failure, low combustion air pressure, high temperature, and low temperature. The system includes a local explosion proof control panel for burner management. The control panel and piping for controls are to be skid mounted. The controls are designed to meet explosion proof requirements. Additional design criteria are listed below:

- vertical thermal oxidizer
- medium btu gas content
- waste gas: 3,000 SCFM @ 1 psig

- 400-600 btu/scf
- fume temperature: -30 to 120 F
- combustion efficiency: 95-99%
- flaring temperature: 1500 F
- fuel for pilot natural gas:
- power requirements: 120 V, 60Hz, 3 Amp

Operating Procedures

The operating procedures will be outlined in the operation documentation provided by the manufacturer. At a minimum, the documentation will cover the proper operating procedures on the following items: flaring chamber, burner, pilot and ignitor, controls, control panel and accessories.

Maintenance

The maintenance procedures are also outlined in the maintenance documentation provided by the manufacturer. At a minimum, the following items should be inspected routinely: the flame arrestor flow capacity and pressure should be periodically checked to verify safe operation, the temperature, combustion efficiency and resonance time should be verified, the interlocks should be tested, inspect for plugs or breaks in the system or the pipes leading to the flare, control and control panel tested, and perform an overall balance to the system.

13.09 Shallow Water Collection and Conveyance

Ground water within the Combe Fill South Landfill, will be collected by a Shallow Ground Water Collection and Conveyance System. This system will consist of nineteen (19) wells with submersible pumps. The pump controls and valving will be located in a concrete vault, above each well. The ground water collected in the wells will be pumped to two separate forcemain headers which will discharge at the top of the equalization tank at the treatment plant.

The ground water collection system is designed to control the ground water elevation levels within the designated areas of the site. The objectives of the ground water collection system is to collect the ground water discharging from the landfill for on-site treatment and therefore minimize contact of fill material with ground water. Each well system contains the submersible pump, a control panel, pressure gauge, check valve, ball valve and a flow meter. An air relief valve manhole will be placed at the high point in each forcemain header to release the small quantities of air that accumulate during operation and the large amounts of air that must be released during start-up in the pipes. In addition, the air relief valve also prevents collapse of the forcemain header due to potential vacuum caused by a break in the line.

13.09.01 Wells

Description

A total of nineteen ground water recovery wells will be installed to collect the ground water from the site and pump to the equalization tank at the treatment plant.

Purpose

The ground water recovery wells will provide a means of collecting the ground water discharging from the landfill for on-site treatment and therefore minimize contact of the fill material with the ground water.

Special Features

The recovery well casing shall be constructed of new 6.625 inch outside diameter and minimum 6.065 inch inside diameter steel well casing with 0.156 inch minimum wall thickness. A minimum five foot section of blank riser casing shall be installed at the bottom of each well to accommodate the pump. Casing lengths will be joined water-tight using threaded and coupled or welded joints.

The well screen will be constructed of stainless steel continuous slot wound wire which will provide corrosion resistance and durable construction since the system will be operating for an extended period of time. A 0.010 inch screen slot size is proposed.

The material used for the filter pack should meet the specifications for the commercially available Morie #00 or an equivalent filter pack. To ensure that a continuous layer of filter pack material surrounds the well screen, the annulus around the well screen must be at least three inches. Thus, a 12-inch boring is proposed.

The well screen will be installed so as to screen across the entire saturated zone within the saprolite. This will result in screen lengths ranging from approximately 25 to 40 feet, depending upon exact well locations and conditions encountered during drilling. The well screen sections will be joined threaded and coupled, or welded joints. The well screen will be joined water tight to the casing using threaded and coupled joints or by welding. The well screen will be packed with a suitable filter pack to a minimum of 2 feet above the top of the screened interval. A minimum 1-foot bentonite slurry seal shall be placed above the filter pack in each well. A cement/bentonite grout will be installed within the annular space above the bentonite seal.

Operating Procedures

Under normal operating procedures, ground water fills the recovery well. The level control is activated at a preset point which activates the submersible pump.

Maintenance

Routine inspections of the ground water recovery wells should be conducted to address the operational needs of the system. The ground water recovery wells should be inspected for balance of the extraction system, accumulation of debris, signs of vandalism, signs of settlement, and other items that may inhibit the optimum extraction rate. If accumulation of debris is noted, the wells should be promptly cleaned. The check and ball valves, the pressure gauge and the flow meter must be routinely checked for proper operation and replaced when needed.

13.09.02 Piping

Description

The entire ground water collection system is below grade. Piping material from the submersible pump to the forcemain header connection will be 1½" stainless steel. The two HDPE forcemain header pipes discharge to a single 8" HDPE forcemain which connects to the equalization tank.

Purpose

The ground water header piping is designed to pump the extracted ground water from the well heads to the equalization tank located at the treatment plant facility.

Special Features

The pipe materials were selected based on the chemical compatibility of the low concentration of chemical compounds that will be placed in direct contact with the ground water extraction system. The size of the forcemain header is designed to minimize the friction losses.

Operating Procedures

Under normal operating conditions, the ground water extraction piping is designed to transport the ground water from the wells to the equalization tank located in the treatment plant facility under pressure.

Maintenance

In anticipation of potential problems, a routine program of inspection and maintenance should be established. Tools and pipe materials should be readily available for routine repair of the line. Prior to entering the vault above the wells or the air relief valve manholes, the air must be monitored by an oxygen meter and an explosimeter to determine if there are any hazards present. The air monitoring regulations outlined in 29 CFR 1926.800 must be followed during air monitoring of the vaults or manholes.

13.09.03 Submersible Pumps

Description

The submersible pumps in each well will be of stainless steel construction to be more compatible with the chemical compounds in the ground water. The pump horsepower ranges from 1/3 to 1 hp depending on the well location and its depth.

Purpose

The submersible pumps are designed to pump the ground water from the wells to the treatment plant for treatment.

Special Features

The submersible pumps selected for the design of this ground water extraction system were chosen to meet the following requirements: optimum performance at each well, chemical compatibility, ease of operation and maintenance, durability.

Operating Procedures

Under normal operation, the submersible pumps will pump the ground water and leachate from the wells to the equalization tank. The ball valve is normally fully open. However, the ball valve at each well can be used to adjust the desired flow by increasing the head which the pump operates against. Increasing the lead, reduces the flow and increases the time it takes to lower the ground water level in the well. The pump on time is therefore increased. As the average ground water elevation is lowered over time, the pump on control setting should be lowered. It is important to note that the pumps should operate for no less than 30 seconds each cycle; pump times of (1) minute or more are desirable.

Maintenance

The installed pumps are intended to remain entirely submerged. During routine maintenance, the pumps must be hoisted out of the well for inspection. Prior to removing any pump, make sure the power supply is off and the ball valve is closed. Once the pump is removed from the well, the pump is inspected on site. Before inspecting a pump, always make sure that power is off and the power supply to the pump is disconnected. After repair of a pump, it must be reinstalled in the same well. Do not interchange pumps between wells.

The control panel must be inspected by a qualified electrician annually. All of the compartments must be cleaned out and the wiring must be inspected for indication of hot spots. All wire connections must be checked to make sure that they are tight. Do not wiggle the wires when the power is on because this can cause arcing and harm the individual standing in front of the equipment. It is also recommended that a record be kept of the model number, frame sizes and settings of all protective devices for future reference. If motors start to trip out on overload, do not increase the protective equipment settings or change sizes of overloads to keep the equipment running. The cause of the overload must be found and corrected.

13.10 Ground Water Treatment System

Description

The ground water treatment system consists of several unit processes, including flow equalization, pH adjustment, metals removal, biological treatment filtration, carbon adsorption and sludge handling. Major process equipment consists of an inclined plate settler, sequencing batch reactors, continuous sand filters, carbon adsorption units, a filter press, several equalization and storage tanks, and transfer and metering pumps. With the exception of the powdered activated carbon and corrosive chemical feeds which are stored in the gas extraction building under high hazard classification, and outdoor tanks as shown on Drawing M-7, the ground water treatment system equipment and controls are located inside the process equipment building. The system will operate at a maximum design flow of 175,000 gpd to treat both ground water and landfill gas condensate.

Purpose

The ground water treatment system is designed to remove BOD5, TSS, TOC, ammonia-nitrogen, volatile organics, heavy metals and total phenolics from the combined ground water - landfill gas condensate waste stream.

Special Features

The treatment process includes all necessary instrumentation and controls for 24-hour operation with single-shift operator attendance. The system equipped with high and low-level alarms and switches and pH, flow-proportional, and manual control of chemical metering. Ancillary equipment for the facility includes an air compressor, a hydropneumatic plant water system, a submersible aerator for the ground water equalization tank, and a submersible mixer and skimmer for the landfill gas condensate equalization tank.

Operation Procedures

The operation of the ground water treatment facility will require operation by qualified, specially trained and licensed operators meeting necessary State of New Jersey certifications. Additionally, trained maintenance technicians may also be required.

The operation procedures for the system will require daily monitoring of equipment, system adjustments, preparation of chemical batches, acquisition of samples, normal maintenance, reports and operation of sludge dewatering equipment.

For a liquid waste treatment system of the complexity of this system, operation in a manner to consistently achieve rigorous effluent limitation will require a formal operation plan. Along with operator training and conductors of careful operating procedures.

To assure successful system operation, it is expected that an operations and maintenance manual will be prepared. This manual should be of sufficient detail to provide operation guidelines for each process of the system. The manual should also contain detailed vendor literature for each major component of the system. The vendor literature should contain equipment description, normal operation procedures, troubleshooting information, maintenance procedures, spare parts data as well as lubrication requirements.

The operation plan should follow a startup training and debagging phase following completion of construction.

Maintenance

Maintenance procedures and troubleshooting information will also be outlined in the maintenance documentation provided by the equipment manufacturers. At a minimum, process performance and effluent quality should be routinely inspected and periodic and scheduled maintenance procedures suggested in the vendors literature adhered to.

13.11 Record Keeping

Following closure activities a survey plat should be developed in accordance with the requirements of 40 CFR Part 264. The plat should be prepared by a licensed surveyor and should show the extent of the low permeability cover, the extent of grading, and property lines. These items should be related to surveyed bench marks. The plat should be filed with the local authority having jurisdiction over land use.

An inspection checklist should be developed and filled out during all routine inspections. As a minimum, the checklist should include discussions of the following items:

- Condition of final cover including delineation of any damaged areas and repair activities;
- Condition of drainage structures;
- Condition of access roads;
- Condition of gas extraction system;
- Condition of gas treatment system;
- Condition of ground water extraction system;
- Condition of ground water treatment system;
- Condition of monitoring wells;
- Other routine maintenance and monitoring activities.

Copies of inspection reports, along with associated repair records, should be maintained for a period of at least thirty years following closure.

13.12 Manpower Requirements

All inspection and maintenance activities should be conducted by a minimum of two people when entry of manholes and other enclosed spaces are included. It is anticipated that operation and maintenance activities associated with the cover, gas extraction and treatment system and shallow ground water will be a full time activity for two people for the three month shake down period following completion of site remediation. This time requirement should decrease during the first year until routine operation and maintenance activities require two people for an average of ten days (20 mandays) each month.

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